NASA

ADVANCED ROTORCRAFT TECHNOLOGY AND TILT ROTOR WORKSHOPS

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VOLUME V
Propulsion Session

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HAA/NASA

ADVANCED ROTORCRAFT TECHNOLOGY

WORKSHOP

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VOLUME V

PROPULSION SESSION

VOLUME V

PROPULSION SESSION

CONTENTS

CHAIRMAN'S REPORT

HAA/NASA ADVANCED TECHNOLOGY WORKSHOP

PROPULSION SESSION

Volume V

CHAIRMAN	Charles Kuintzle	Avco Lycoming
TECHNICAL SECRETARY	Warner Stewart	NASA-Lewis Research Center

The description of the NASA technical programs was performed by D. Poferl of NASA-Lewis Research Center.

Both Subsessions were under the Chairmanship of Charles Kuintzle.

Airframer Subsession - Presentors

Dr. Kenneth Rosen
Sikorsky Aircraft

Carl Matthys
Bell Helicopter Textron

Rodney Taylor
Hughes Helicopters

Gilbert Beziak
Aerospatiale Helicopter

David Woodley
Boeing Vertol

Propulsion Subsession - Presentors

S. M. Hudson
Detroit Diesel Allison

Arnold Brooks
General Electric Co.

Nick Hughes
AiResearch Manufacturing

Richard McLachlan
Pratt & Whitney Aircraft of Canada

Dennis Lewis
Rolls Royce, Ltd.

Edward Peace
Avco Lycoming

HAA/NASA TECHNOLOGY WORKSHOP

PROPULSION SESSION

Volume V

INTRODUCTION

The expressed needs and priorities of the civil helicopter users, the existing NASA research efforts, and technology requirements as perceived by leading airframe and engine manufacturers have been addressed, compared, and evaluated. Specifically, the observations and conclusions of these areas as they relate to the helicopter propulsion system are reported.

NASA's objective to maintain effective and continuous technology growth in the proper direction to address the needs of civil aviation is a challenging one. Specific programs must be focused primarily at the component level to provide the basis of generic improvements which are ultimately applicable for incorporation into complete propulsion systems. A vital ingredient in the proper planning and implementation of programs which benefit the industry to the largest extent, particularly with the current funding restraints and almost unlimited technology demands, requires a visibility that can only be achieved through very close communication and cooperation with airframe and propulsion system manufacturers as well as the final civil helicopter users.

The helicopter industry has, since its infancy, benefited from the close coordination of the propulsion system manufacturer, the airframe manufacturer, and the final user. The engine manufacturer is normally an active member of

the helicopter manufacturers team throughout the design, development, and application cycles of the helicopter. Continuous feedback and communication of customer reactions and requirements is the normal business philosophy.

R&D activities conducted by NASA in the field of propulsion system advanced rotorcraft technology are important to the civil helicopter user in terms of how they translate into business related factors. To the user, improved public image of the helicopter is important along with economical operation and high reliability. Improved range and all weather capability are important factors. The final user is not as interested in the specific component technology details which may be required but, understandably, is interested that technology improvements ultimately lead to improvements in the areas of expressed concern.

CIVIL HELICOPTER USER NEEDS

The overall task to develop relationships between user needs, existing and planned NASA efforts, and technology requirements as perceived by airframe and propulsion system manufacturers, is a complex one. One would expect that there would be significant differences in opinion based upon the different perspectives of those involved. Interestingly enough, the active give and take presentations and discussions throughout this Workshop showed surprising consistency in identifying areas where major technology advancements are required. The twelve presentations made by civil helicopter users (see Volume II) addressed a very wide range of needs and concerns related to the overall helicopter system.

Considerable commonality in user needs and concerns exist relative to improvements desired in helicopter propulsion systems. The two areas of almost universal concern are reliability and the need for a true single engine contingency power rating. Users stated that there are too many transmission and engine failures. Twin engine helicopters are strongly favored from a safety viewpoint, however, OEI contingency power ratings are not sufficient to allow full OEI capability.

Excessive transmission and engine noise within the passenger compartment is another area in which users believe should be addressed. In addition, improved anti-icing capability to assure all weather operation is essential. Reduced specific fuel consumption is a need voiced by many of the users. This need is based more upon the desirability for increased operational range rather than from a petroleum conservation viewpoint. However, all users agree that the need for petroleum conservation is axiomatic.

Reduced propulsion system costs, improved fuel and air filtration, and improved corrosion resistance were further requirements expressed by users as well as the need for basic research work in more concept advanced power systems.

AIRFRAME MANUFACTURERS TECHNOLOGY NEEDS

A number of specific technological needs were expressed by the helicopter airframe manufacturers. These include support of low cost electronic fuel controls, high contact ratio gear development for improved transmissions, engine diagnostics, composite material development to reduce weight, variable geometry engines, real OEI contingency power and a high technology turbine

engine in the 300 horsepower class. The use of electronic fuel controls in engines of the future is expected to provide a major step in the improvement of the reliability of small engines which currently suffer an excessive number of control difficulties. In addition, the utilization of electronic controls is expected to result in reduced overall system weight as well as reduced pilot workload. Helicopter reliability will also be improved from integrated transmissions, eliminating a separate reduction gearbox on the engine.

Transmission noise reduction is an area where improvement is also required. Current technology does not allow accurate predicting and controlling of transmission generated noise. The requirements for improved transmission reliability and reduced noise are technically compatible objectives, but the real challenge lies in being able to accomplish these along with weight reductions. High contact ratio gearing combined with special acoustical treatment and composite materials for transmission cases could provide the answer.

R&D effort is required to define more accurately the icing environment at low altitudes in which the helicopter normally operates. Consistent with this definition must become the necessary development facilities to allow proper test and validation of new configurations at these conditions.

Echoing the users demands for real OEI contingency power, the helicopter manufacturers add that helicopter payload is usually limited to account for engine failures that rarely happen. That is, at the critical takeoff power or in route at high gross weight far from a safe landing area. In order to provide the smallest, lightest, and most efficient powerplants for normal

operating conditions and within the current constraints of OEI certification requirements, the ratio of OEI power to takeoff power rating must be larger than current practice.

Little technological effort is being directed towards the helicopter reciprocating engine at the current time. The threat of aviation gasoline shortages in the near term could leave many small operators without a suitable powerplant unless either an effective approach to utilize alternate fuels in reciprocating engines is developed or a small turbine engine powerplant of competitive costs to the reciprocating engine comes into the future.

ENGINE MANUFACTURERS TECHNOLOGICAL NEEDS

Engine manufacturers emphasize many of the same requirements as the users and airframe manufacturers. Increased emergency ratings leading to increased "Category A" payloads, is considered to be the most important element that needs to be addressed. Several approaches to obtain improved ratings within current regulations and by applying current technology were discussed including a unique approach of "power pairs." This concept is based upon a rational choice of a combination of emergency and takeoff power ratings to give the maximum possible increase in 2 1/2 minute rating over the takeoff rating by selecting the power conditions on a basis that just allows passing the FAA and CAA certification tests. It is important to note that current FAA and CAA certification practices are believed to be overly stringent in regard to the demonstrated requirements for OEI operation. For example, the current FAA requirement for certification requires that the engine operate at the 2 1/2 minute power rating for over two hours of the 150 hour certification test,

whereas, in service, the engine operation at this rating could be limited to only a few minutes in the total lifetime of the engine prior to overhaul, inspection, or parts replacement. This requirement seriously limits the selection of the OEI engine rating and effects all other power ratings in order to allow sufficient margin to successfully demonstrate the ability of the engine to meet the overall certification test requirements. As a result, engines are larger, heavier, and burn more fuel than would be the case if the engine could be designed and certified to a test cycle which would require only a few minutes of emergency rating power demonstration. The improvements in power ratings which could be expected from increased cycle temperatures through the use of directly solidified as well as single crystal blading were also discussed.

Current inaccuracies in gas temperature, torque, and rotor speed instrumentation forces a rating conservatism of as much as 10% in some installations. Engine manufacturers point out that giving away this much usable power to compensate for inaccurate instrumentation seriously negates many of the component technology improvements that engine manufacturers work so deligently to achieve. It is evident that improved user installed engine power ratings are achieveable through improved instrumentation with existing powerplants.

Improved efficiency, compressors, and turbines will be a continuing demand. However, it is recognized that quantum improvements in these areas is not likely. The use of recuperators now successfully employed in vehicular turbine power-plants, should be pursued with increased emphasis as a means of reducing specific fuel consumption to improve helicopter range.

Improved reliability through the increased application of electronic controls is considered by practically all of the engine manufacturers as being a positive direction for the future.

NASA ROTORCRAFT PROPULSION PROGRAM

The NASA-Lewis Rotorcraft Propulsion Program, consistent with the 1978 task force report on Advanced Rotorcraft Technology, addresses many of the concerns faced by the users and the technology demands expressed by the airframe and engine manufacturers. Program emphasis is on improved engine and power transfer reliability and maintainability, reduced fuel usage, improved environmental capability and acceptability, and reduced acquisition and operation costs. The major elements include system studies, components, transmissions, and overall system integration.

Engine component research and technology development includes activity on compressors, combustors, and turbines with the major emphasis on improved performance, decreasing costs, and increasing reliability. A further emphasis on improved reliability through research in the areas of transmissions, lubrication, bearings, and seals is ongoing. In addition, the effects of distortion on load transient capability is being investigated on a turboshaft engine. An advanced digital electronic controls program has been implemented and a study is in progress to identify problem areas and potential solutions and to assess the benefits of diagnostic and condition monitoring control systems.

Unique advanced propulsion system studies for high speed rotorcraft are underway including, cycle analysis, conceptual design, and economic analysis. A program

is being formulated to evaluate a convertible engine concept which will be used to investigate the conversion from thrust power to shaft power needed for high speed rotorcraft.

A program is in the planning stage to explore new concepts for contingency power operation. Both requirements and certification methods will be considered. Although the program is still in the early stages, it is anticipated that concepts such as injecting water into cooling air for higher temperature operation, variable turbine cooling and burnout power will be investigated.

In general, the NASA Rotorcraft Propulsion Program is supported by the user community and the helicopter airframe and engine manufacturers, although suggestions relative to prioritization and specific direction of some programs are offered. A comparison of expressed user needs with the current NASA propulsion programs and recommendations for future related programs is given in the Workshop Summary Forms which follow.

GENERAL DISCUSSION

The Propulsion Session of the Advanced Rotorcraft Technology Workshop provided a useful vehicle to draw together the civil helicopter users, the airframe and engine manufacturers and the NASA-Lewis Research Organization. The users left little doubt as to what they wanted in the initial propulsion system. In simple terms they wanted a low cost, fuel efficient, light weight, modular construction, quiet, all weather, reliable propulsion system with twin engine safety and full OEI contingency power capability. The current NASA Rotorcraft Propulsion Program

elements address, in varying degrees, these demands.

The inlet distortion element of the NASA program, although useful to assess the influence of inlet distortion on a specific engine model, does not promise direct benefit to the civil helicopter user. Also, the controls program is directed at a specific engine model and is not generic enough in nature to benefit turbine engines in a general sense. Electronic controls for turbine engines is a specialty item in the industry and, with the exception of development of basic technology such as adaptiveness to engine conditions and helicopter operation, is best left to the controls manufacturer.

Workshop discussions made obvious that there are many ways to get the same end results. Increased range or fuel efficiency can be achieved by engine specific fuel consumption reductions, by reduced helicopter system weight, and by improved airframe aerodynamics. The best approach to a large degree, depends on the level of technology available at any point in time. Although the development of new engines is an expensive and long term path, it is one that must always be followed. The application of available technology such as more extensive use of composits for airframe structures could offer a shorter term solution.

To the civil helicopter user the real measure of the helicopter's usefulness is summed up in one word - "profit." The major driver is helicopter availability which can be translated into terms repeatedly used during the workshop --- "system reliability" and "all-weather capability." Fuel consumption is important both from direct operating costs standpoint and useful range.

At the current time, NASA programs do not address the helicopter reciprocating engine to any significant degree. Until such time that the industry makes available a small, high performance turbine engine comparative in price to the reciprocating engine, the low gross weight helicopter (i.e. under 6000 lbs.) is dependent upon the reciprocating engine. Decreasing availability coupled with the continuing increasing cost of aviation gasoline is generating a major threat to the survival of helicopters in this category. Programs to develop the necessary technology to allow the reciprocating engine to burn more readily available fuels in an efficient and dependable manner should be considered.

Without question, the single element attracting the most interest during this workshop was the need for real OEI contingency power. This requirement is identified as the number one priority by the users and by the airframe and engine manufacturers. In order to effectively address this universal concern, it is recommended that a joint civil helicopter user, industry, NASA, and FAA workshop be planned to address approaches to obtain regulatory recognition of special OEI burnout ratings in combination with realistic certification requirements for these ratings.

CONCLUSIONS

No obvious quantum technology improvements that will specifically address user needs are on the horizon. The needed improvements are going to be the result of expensive evolution and extensions of current technology. The current NASA propulsion programs are generally supported. These programs address the user needs but appear to be over comprehensive relative funding levels available.

The three areas where either additional effort is required or where programs should be implemented include improved OEI contingency power, alternate fuels for helicopter reciprocating engines, improvement of the reliability and accuracy of engine sensors.

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA PROPULSION SUB-AREA ENGINE TECHNOLOGY

User Requirement	Current Related NASA Program	Recommendations for Future
Real OEI Contingency Power	Contingency Power Program in early planning phases to explore economic penalties and feasibility of emergency power. Will investigate "burnout power" requirements and certification methods.	Major emphasis should be directed to this program. Should be reassessed in view of priority placed upon this area by users and manufacturers. A joint user, industry, NASA, and FAA Workshop on OEI Contingency Power Ratings should be the vehicle to formulate the general regulatory and technological approaches to meet this requirement.
Improved Reliability (Reduced Noise)	o Transmission (conventional) o Transmissions (unconventional) o Very Large Transmissions o Diagnostics All of these programs involve technology development targeted toward improved powerplant reliability. The transmission program combine the strengthening of design approaches as well as increased life, reduced weight, and reduced noise. **Diagnostics program is study activity** to identify diagnostic and monitoring systems to improve system safety and reliability.	Programs are all well structured and, if successful, should yield technology developments that will improve reliability of future powerplants. Some of the objectives are somewhat incompatible, i.e. improved reliability, reduced noise vs reduced weight, reduced cost. Currently, users would accept improved reliability and reduced noise at equal (and probably higher) weight and cost.

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA PROPULSION SUB-AREA ENGINE TECHNOLOGY

User Requirement	Current Related NASA Program	Recommendations for Future
Advanced Powerplant Concepts	o Advanced Propulsion Systems o Convertible Engine System Technology The Advanced Propulsion System Program supports studies targeted at advanced conceptual designs. The Convertible Engine Program is an evaluation activity to demonstrate transfer of fan thrust to shaft power using variable exit guide vanes.	Both of the current programs are endorsed. The propulsion studies should be extended to include the reevaluation of tip propulsion with latest technology developments.

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA PROPULSION SUB-AREA AIRFRAME TECHNOLOGY

User Requirement	Current Related NASA Program	Recommendations for Future
Improved Range	o <u>Compressors</u> o <u>Combustors</u> o <u>Turbines</u> These programs are all directed at extending the basic technology areas related to the design and development of advanced components for high pressure ratio, high temperature, high performance turbine engines.	These programs are strongly endorsed. They provide the nucleus of basic research and development in the aerothermodynamics of turbine engines. Objectives cover a very wide scope considering the funding levels available. Regenerators for aviation gas turbines should be addressed. This currently untapped potential could yield larger improvements in aircraft range in a shorter time frame than the evolution of other component technology.
Improved All-Weather Capability	<u>Icing Program</u> is directed at several areas including:- o Analytical activities directed at droplet trajectories and inter-actions with engine inlets along with experimental verification thereof. o Development of research models and ice protection concepts. o Update icing facilities.	This program is well structured and is endorsed, however, large scope of program objectives relative to limited level of funding.

OVERVIEW - NASA-LEWIS RESEARCH CENTER
ROTORCRAFT PROPULSION PROGRAM

D. Poferl

The overall objective of the rotorcraft propulsion program is to develop analytical design tools, component technology, and advanced propulsion concepts for future rotorcraft. Program emphasis is on improved engine and power transfer reliability/maintainability, reduced fuel usage, improved environmental capabilities and acceptability, and reduced acquisition and operation costs. The program is consistent with the 1978 Task Force Report on Advanced Rotorcraft Technology. The major elements include systems studies, components, transmissions and overall system integration.

Engine component research and technology includes analysis, design and test of compressors, combustors, and turbines to improve performance, decrease cost and increase reliability. Transmission research and technology includes both component and full power transmission testing. Lubrication, bearing, seals and gearing are being improved to extend life, reliability and load carrying capabilities of both conventional designs and unconventional designs such as hybrid traction drives. The engine component research and technology programs are jointly sponsored by NASA and USARTL.

The General Electric T700 turboshaft engine is being used as a research tool to understand the effects of distortion on load transient capability. Also, an advanced digital electronic controls program for improved safety and engine stablization has been implemented for testing in the FY 82 time period. To further enhance engine and power transfer reliability, a study is in progress to identify problem areas and potential solutions, and to assess the benefits of diagnostic and condition monitoring control systems.

System studies to identify unique advanced propulsion systems for high speed rotorcraft are under way. These studies which include cycle analysis, conceptual design, and economic analyses will be used to guide NASA research in the area of advanced propulsion systems for future high productivity rotorcraft. Configuration types to be considered include X-Wing, Advancing Blade Concept (ABC) and the folded tilt-rotor.

A major program to evaluate a convertible engine concept is in the final formative stages. A modified TF34 turbofan engine will be used to investigate the conversion from thrust power to shaft power needed for high speed rotorcraft. Dynamic power transfer will be accomplished by using variable inlet and exit fan compressor guide vanes which off-load the fan during shaft power operations. The electronic digital control modes that will be used for these tests will simulate an x-wing type configuration and mission requirements. This program is a joint NASA and Defense Advanced Research Projects Agency (DARDA) program.

Advances in rotor, propulsion system, and rotorcraft deicing are being explored both at the Lewis Research Center and the Ames Research Center. Research models are being developed to examine new optimized ice protection systems with eventual full scale testing of the most promising concepts.

Plans are being formulated to explore new concepts for contingency power operation. Both requirements and certification methods will be considered. Concepts such as injecting water into cooling air for higher temperature operation, variable turbine cooling and burn-out power will be investigated.

The 1978 Task Force reports indicate that the present component improvements will start to be investigated in system tests beginning in FY 1984. Propulsion and Transmission Research activities are vigorously being pursued to achieve this goal. A continuing advocacy for rotorcraft is needed to assure success of these ambitious objectives of the rotorcraft propulsion program.

OVERVIEW

NASA LEWIS RESEARCH CENTER

PROPULSION PROGRAM

NASA OAST

PROPULSION

PURPOSE

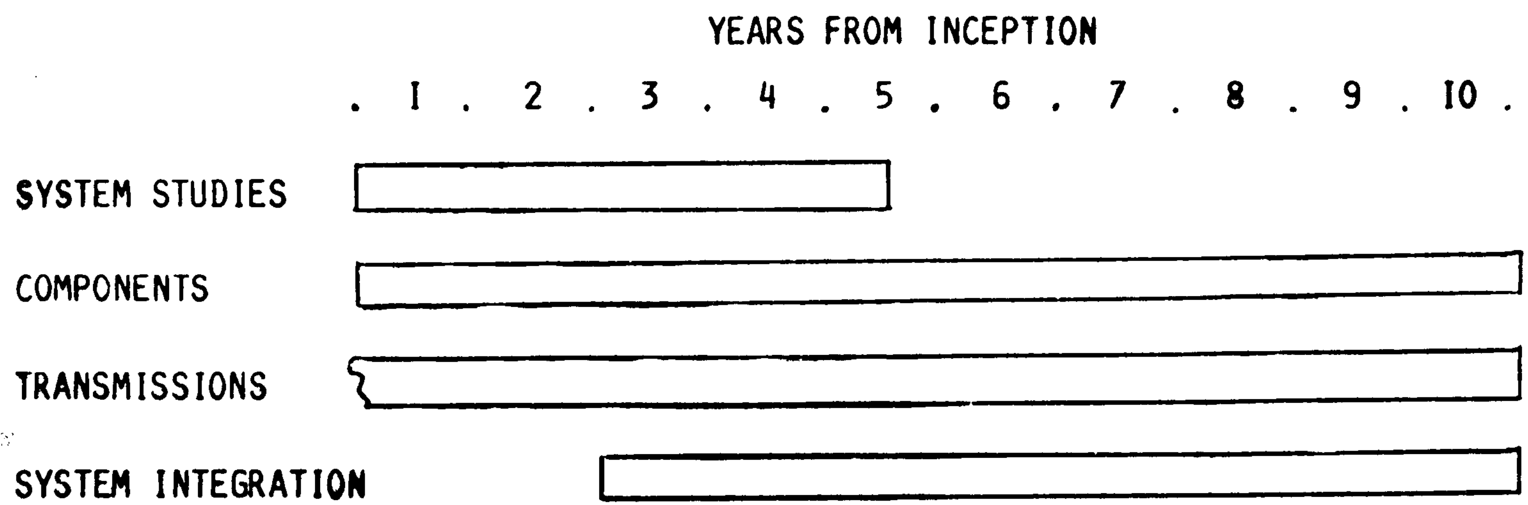
IMPROVE ENGINE AND POWER TRANSFER RELIABILITY/MAINTAINABILITY

IMPROVE ENGINE FUEL CONSUMPTION AT CRUISE POWER

IMPROVE ENVIRONMENTAL ACCEPTABILITY

REDUCE COSTS

PROPULSION PROGRAM ELEMENTS



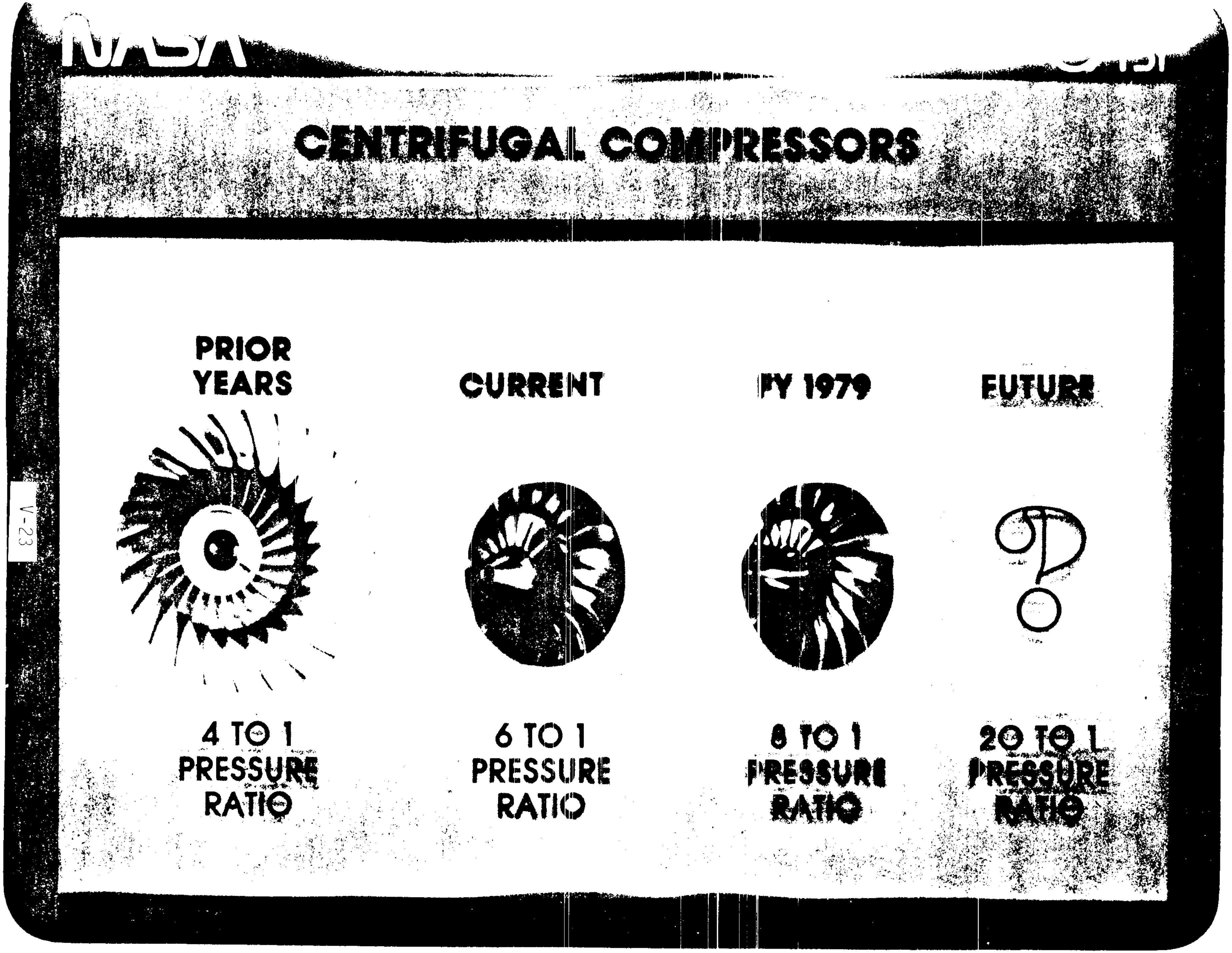
PROPULSION

EXECUTIVE SUMMARY OF ROTORCRAFT PROGRAMS

(NARRATIVE)

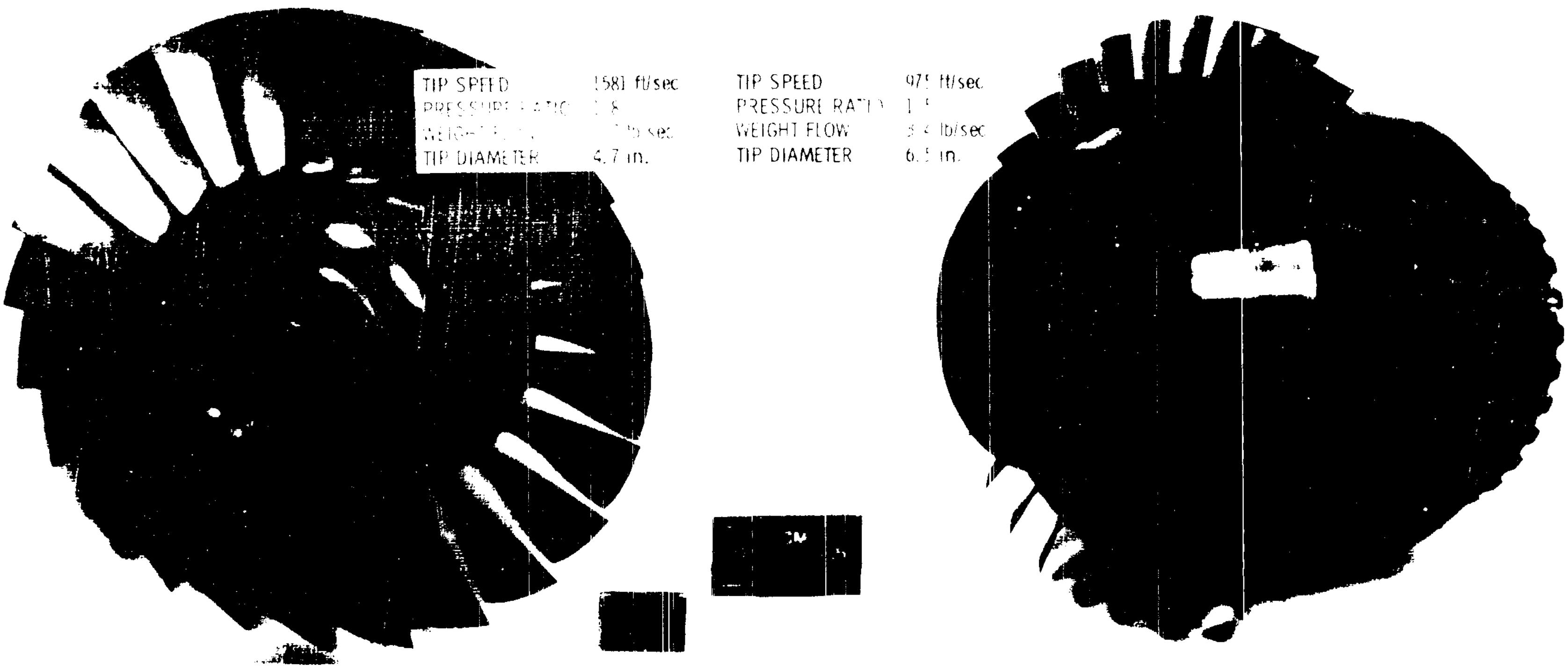
ENGINE COMPONENT RESEARCH AND TECHNOLOGY

MAJOR TASK	DESCRIPTION	CONTACTS/RTOP
COMPRESSORS:	DESIGN, FABRICATE, AND EXPERIMENTALLY EVALUATE ADVANCED STAGED AXIAL/CENTRIFUGAL, SCALED AND VARIABLE FLOW COMPRESSORS. IMPROVED PERFORMANCE AND DETAILED INTERNAL FLOW MEASUREMENTS TO ADVANCE THE STATE-OF-ART AND UPDATE AND VERIFY ANALYTICAL DESIGN TECHNIQUES AND COMPUTER CODES. UPDATE FACILITIES.	C. BALL FAN & COMP BR/LERC 6835/505-42-22, 532-06-12


NASA
CENTRIFUGAL COMPRESSORS
PRIOR YEARS
CURRENT
FY 1979
FUTURE
4 TO 1 PRESSURE RATIO
6 TO 1 PRESSURE RATIO
8 TO 1 PRESSURE RATIO
20 TO 1 PRESSURE RATIO

SMALL AXIAL COMPRESSORS

SCALED STAGES

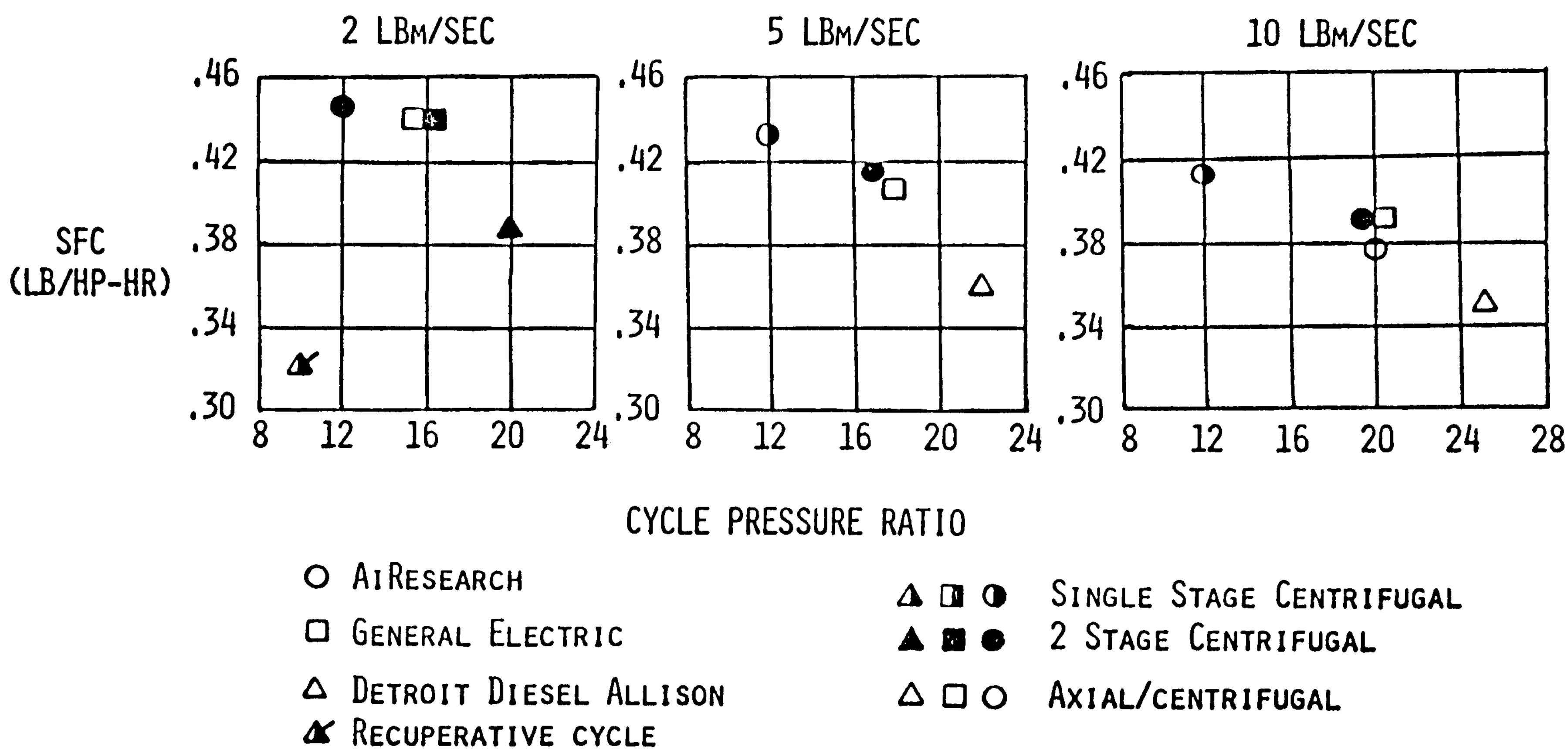


INLET STAGE

MIDDLE STAGE

SMALL COMPRESSOR DESIGN STUDY CONTRACT

- RECOMMENDED CONFIGURATIONS -



PROPULSION

EXECUTIVE SUMMARY OF ROTORCRAFT PROGRAMS

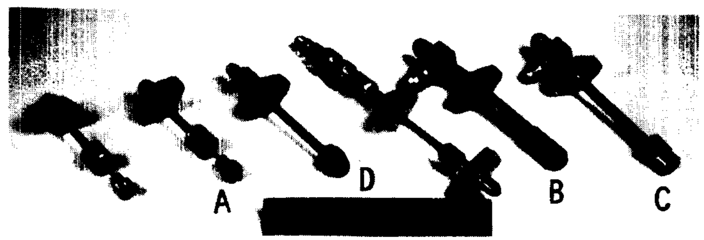
(NARRATIVE)

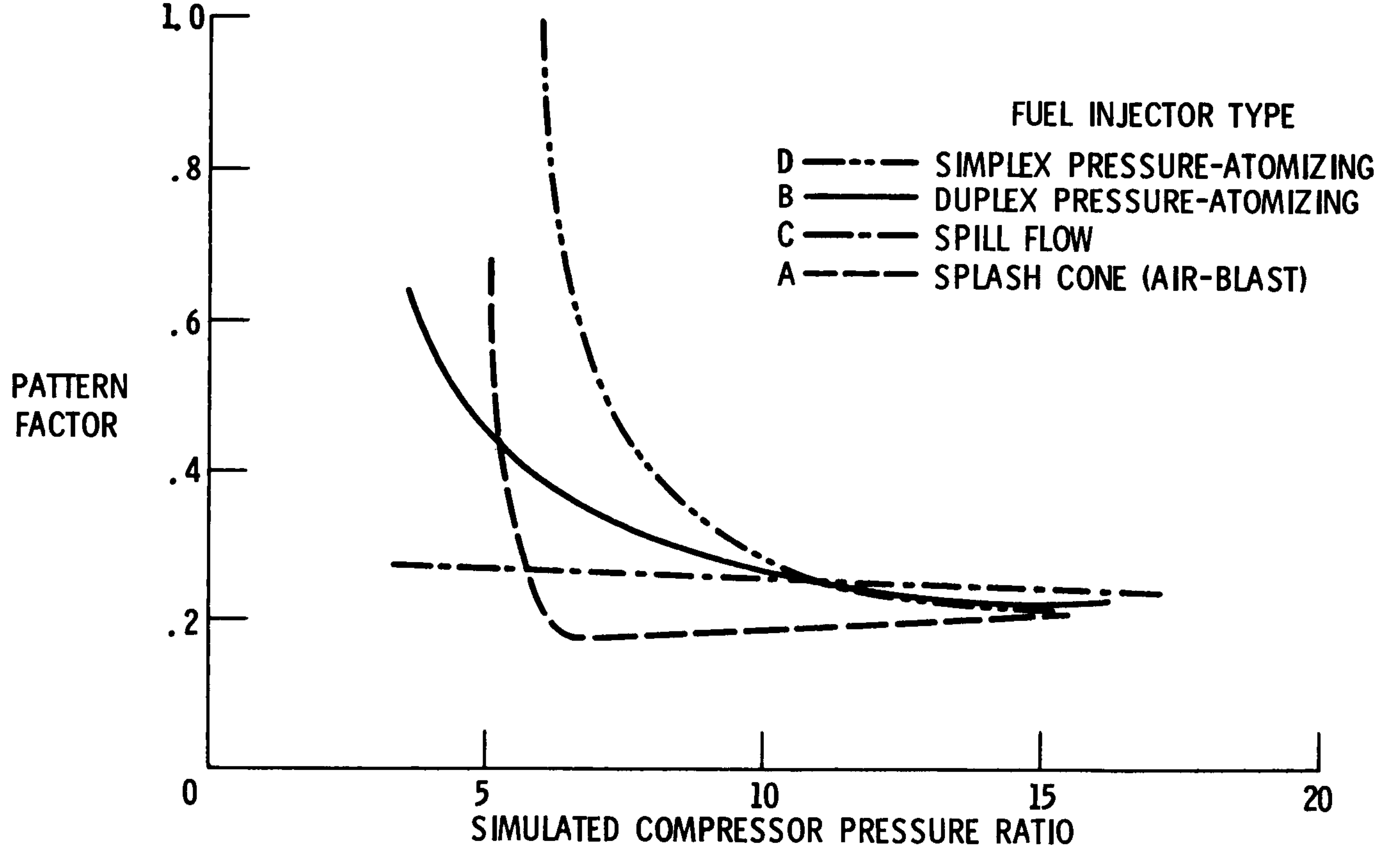
ENGINE COMPONENT RESEARCH AND TECHNOLOGY

MAJOR TASK	DESCRIPTION	CONTACTS/RTOP
COMBUSTORS:	DEVELOP ADVANCED TECHNIQUES FOR INCREASED OUTLET TEMPERATURES, PRESSURES, EFFICIENCY AND DECREASED PATTERN FACTORS AND POLLUTION BY IMPROVED COOLING, FUEL INJECTOR DESIGNS AND COMPUTATIONAL MODELING FOR 300-1500 SHP RANGES. REVERSE FLOW AND RADIAL OUTFLOW COMBUSTORS ARE BEING DESIGNED, FABRICATED, TESTED AND ANALYZED.	E. LEZBERG COMBUSTION BR/LERC 6860/505-32-32, 532-06-12

SMALL COMBUSTOR TECHNOLOGY

EFFECT OF FUEL INJECTOR TYPE ON PERFORMANCE





- SPILL FLOW AND SPLASH CONE INJECTORS PROVIDE LOW PATTERN FACTORS

PROPULSION

EXECUTIVE SUMMARY OF ROTORCRAFT PROGRAMS

(NARRATIVE)

ENGINE COMPONENT RESEARCH AND TECHNOLOGY

MAJOR TASK	DESCRIPTION	CONTACTS/RTOP
TURBINES:	ADVANCE COOLING, INCREASED TEMPERATURE AND PERFORMANCE, MECHANICAL INTEGRITY AND ADVANCE DESIGN TECHNIQUES WILL BE EVALUATED BY DESIGN, FABRICATION AND TESTS. SCALING EFFECTS, HIGH WORK FACTOR TURBINES, HIGH WORK TRANSONIC TURBINES, FABRICATION OF A CASTED BONDED COOLED MULTIPIECE ROTOR AND VARIABLE GEOMETRY TURBINES ARE INCLUDED IN THE NEAR TERM PLANS WITH AN APPROPRIATE NEW WARM SMALL TURBINE FACILITY.	H. ROHLIK TURBINE BR/LERC 6131/505-32-22, 532-06-12

SMALL TURBINES
BROAD OBJECTIVES

1. APPLY LARGE TURBINE TECHNOLOGY TO SMALL MACHINES

2. IMPROVE AERODYNAMICS AND COOLING TO MAXIMUM WITHIN LIMITS IMPOSED BY MATERIALS AND FABRICATION TECHNIQUES

PROPULSION

EXECUTIVE SUMMARY OF ROTORCRAFT PROGRAMS

(NARRATIVE)

TRANSMISSION RESEARCH AND TECHNOLOGY

MAJOR TASK	DESCRIPTION	CONTACTS/RTOP
TRANSMISSIONS: (CONVENTIONAL)	DEMONSTRATE AND DEVELOP STATE-OF-ART AND ADVANCED CONVENTIONAL TRANSMISSIONS WITH ADVANCED MECHANICAL COMPONENTS (BEARINGS, GEARING, LUBRICATION) TO INCREASE TRANS. LIFE BY 200 PERCENT, LOAD CARRYING CAPACITY BY 50 PERCENT AND SURVIVABILITY BY 400 PERCENT.	E. ZARETSKY BEARING, GEARS, AND TRANS. SEC./LERC 6104/511-58-12
TRANSMISSIONS: (UNCONVENTIONAL)	DEMONSTRATE AND DEVELOP UNCONVENTIONAL APPROACHES SUCH AS HYBRID TRACTION DRIVES WHICH ARE MORE COMPACT AND MORE RELIABLE WHILE BEING LESS COSTLY AND QUIET.	

511-58-11 HELICOPTER TRANSMISSION SYSTEM TECHNOLOGY

TARGETS

- DETERMINE THE OPERATING CHARACTERISTICS INCLUDING SURVIVABILITY TIMES OF CURRENT STATE-OF-THE-ART HELICOPTER TRANSMISSIONS AND COMPARE THEM TO ADVANCED TECHNOLOGY TRANSMISSIONS (FY 1981).
- DEMONSTRATE AND DEVELOP ADVANCED MECHANICAL COMPONENTS TECHNOLOGY IN CONJUNCTION WITH STANDARD TYPE TRANSMISSIONS WHEREBY TRANSMISSION LIFE IS INCREASED BY 200 PERCENT; LOAD CARRYING CAPACITY IS INCREASED BY 50 PERCENT AND SURVIVABILITY IS INCREASED BY 400 PERCENT (FY 1983).
- DEMONSTRATE AND DEVELOP HYBRID TRACTION DRIVES WHICH ARE MORE COMPACT AND MORE RELIABLE THAN CURRENT STANDARD TRANSMISSIONS WHILE BEING LESS COSTLY AND QUIETER (FY 1983).

PROPULSION

EXECUTIVE SUMMARY OF ROTORCRAFT PROGRAMS

(NARRATIVE)

ENGINE SYSTEM TECHNOLOGY

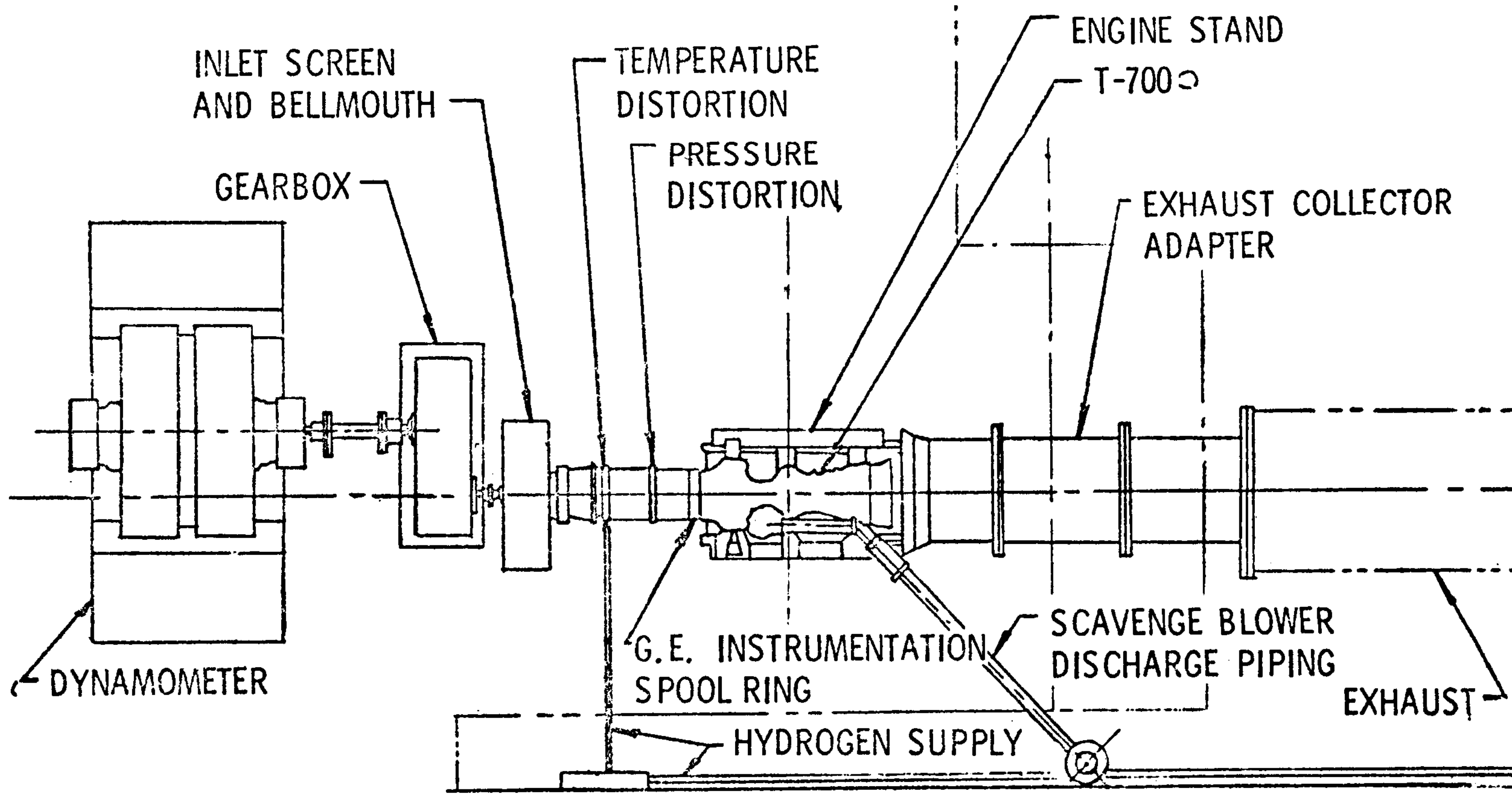
MAJOR TASK	DESCRIPTION	CONTACTS/RTOP
DISTORTION TECH.:	INVESTIGATE DISTORTION EFFECTS OF TEMP, PRESS, AND COMBINED TEMP-PRESS ON A MODERN TURBOSHAFT ENGINE TO IDENTIFY DISTORTION TRANSFER MECHANISMS, LOAD TRANSIENT CAPABILITY AND THE GENERAL DISTORTION PROBLEMS. BOTH STEADY STATE AND TRANSIENT TESTS ARE BEING CONDUCTED.	R. WILLOH TURBINE ENG BR/LERC 6624/505-05-22

HELICOPTER ENGINE PROGRAM

PHASE I - T700 - DISTORTION EFFECTS

- EVALUATE EFFECTS ON STEADY-STATE PERFORMANCE OF STEADY-STATE PRESSURE DISTORTION COMBINED WITH STEADY-STATE AND TRANSIENT TEMPERATURE DISTORTION FY 80/81
- EVALUATE TRADE-OFF OF TRANSIENT LOAD CAPABILITY AND STABILITY MARGIN WITH AND WITHOUT VARIOUS TYPES OF INLET DISTORTION FY 81
- OBTAIN BASE-LINE PERFORMANCE ON COMPRESSOR CONFIGURATION FOR ABOVE AND FUTURE EFFORTS USING THIS ENGINE FY 80

TEST CELL SCHEMATIC



PLANNED CAPABILITIES:

DYNAMOMETER - GEARBOX

- 2500 hp, GROWTH POTENTIAL TO 5000 hp
- POLAR MOMENT OF INERTIA: 0.4 - 0.6 SLUG-ft^2
- TIME CONSTANT (COMMAND TO IMPOSED TORQUE): 1 SEC

TEMPERATURE DISTORTION

- UP TO 300^0 F RISE IN INLET TEMP
- RAMP RATES TO 10 000^0 F/SEC
- 8 INDIVIDUALLY CONTROLLED SECTORS

PRESSURE DISTORTION

- SCREEN PATTERNS

INLET - EXHAUST

- ATMOSPHERIC INLET
- ATM. OR ALT. EXHAUST

PROPULSION

EXECUTIVE SUMMARY OF ROTORCRAFT PROGRAMS

(NARRATIVE)

ENGINE SYSTEMS TECHNOLOGY

MAJOR TASK	DESCRIPTION	CONTACTS/RTOP
CONTROLS:	EVALUATE A MICROPROCESSOR CONTROL SYSTEM DESIGN ON A CURRENT TURBOSHAFT ENGINE AND UPDATE THE MATH MODEL TO SIMULATE ENGINE TRANSIENT OPERATION. DEVELOP ADVANCED CONTROL COMPONENTS, SENSORS, ELECTRONICS, CONTROL ARCHITECTURE AND ACTIVE STABILIZATION CONTROL SYSTEMS FOR IMPROVED SAFETY, RELIABILITY AND DECREASED MAINTENANCE.	J. SELLERS PROP. SYS. CONT. SEC/LERC 6916/532-06-12

ROTORCRAFT PROPULSION CONTROLS

TECHNOLOGY NEEDS:

- HIGHER RELIABILITY
- LOWER COST
- ENGINE/ROTOR/DRIVE SYSTEM INTEGRATION
- REDUCED PILOT WORKLOAD

T 700 CONTROLS

OBJECTIVES:

- FULL-AUTHORITY DIGITAL CONTROL WITH INTEL 8086 MICROPROCESSOR
- EVALUATE SENSOR FAULT ACCOMMODATION TECHNIQUES
- SUPPORT CONTROL INTEGRATION PROGRAMS AT AMES:

    ROTOR/ENGINE/DRIVE TRAIN MODELING

    PILOTED SIMULATION

PROPULSION

EXECUTIVE SUMMARY OF ROTORCRAFT PROGRAMS

(NARRATIVE)

ENGINE SYSTEMS TECHNOLOGY

MAJOR TASK	DESCRIPTION	CONTACTS/RTOP
DIAGNOSTICS:	CONTRACTED ARC, LERC STUDY EFFORT TO IDENTIFY MAJOR SHORT-LIFE, UNRELIABLE, HIGH-MAINTENANCE ENGINE AND POWER TRANSFER COMPONENTS, SUGGEST SOLUTIONS, ASSESS OVERALL ECONOMIC BENEFITS AND NEW TECHNOLOGIES IS IN PROGRESS. DIAGNOSTIC AND MONITORING SYSTEMS WILL BE IDENTIFIED WITH NASA RESEARCH OPTIONS TO IMPROVE SYSTEM SAFETY AND RELIABILITY.	R. KOENIG, J. ZUK ROTORCRAFT PROG. OFFICE LERC, ARC/6604/6569

PROPULSION SYSTEM RELIABILITY/MAINTAINABILITY STUDY

OBJECTIVES:

- IDENTIFY MAJOR SHORT-LIFE, UNRELIABLE, HIGH-MAINTENANCE ENGINE AND POWER TRANSFER COMPONENTS
- IDENTIFY SOLUTIONS INCLUDING PERFORMANCE, WEIGHT AND COST TRADEOFFS
- ASSESS OVERALL CONFIGURATION CHANGES AND PROMISING NEW TECHNOLOGIES
- IDENTIFY COST BENEFITS OF DIAGNOSTIC AND MONITORING SYSTEMS
- ADVISE NASA OF RESEARCH OPTIONS

PROPULSION
EXECUTIVE SUMMARY OF ROTORCRAFT PROGRAMS
(NARRATIVE)
HIGH SPEED ROTORCRAFT

MAJOR TASK	DESCRIPTION	CONTACTS/RTOP
ADVANCED PROPULSION SYSTEMS	SYSTEMS STUDIES TO IDENTIFY UNIQUE ADVANCED PROPULSION SYSTEM CHARACTERISTICS FOR HIGH SPEED (250-500 KNOTS) ROTORCRAFT ARE BEING STARTED. CYCLE STUDY, CONCEPTUAL DESIGNS AND ECONOMIC ANALYSES WILL BE CONDUCTED AND USED TO GUIDE NASA RESEARCH ACTIVITIES FOR REDUCED COST, FUEL USAGE, NOISE AND INCREASE PRODUCTIVITY, SAFETY AND RELIABILITY.	W. STRACK PROPULSION SEC/LERC 6167/532-06-12

RTOP 532-06-12

ADVANCED ROTORCRAFT PROPULSION TECHNOLOGY

CONVERTIBLE ENGINE STUDIES

OBJECTIVES

- IDENTIFY PERFERRED PROPULSION SYSTEM CONFIGURATIONS
- IDENTIFY KEY TECHNOLOGIES
- DETERMINE CONVERTIBLE ENGINE BENEFITS

SCOPE

- ABC, X-WING, FOLDED TILT-ROTOR VEHICLE TYPES
- 250 - 500 KNOT DESIGN CRUISE SPEEDS
- POWERPLANT CONFIGURATIONS
  - VIGV FAN
  - VARIABLE PITCH FAN/PROP
  - INDEPENDENT POWER TURBINE
  - REMOTE TURBINE-HOTGAS DUCTS
- PARAMETRIC CYCLE & STAGING ANALYSIS
- PREFERRED POWERPLANT RECOMMENDATIONS
  - LOW-SPEED
  - HIGH-SPEED
- FUTURE RESEARCH RECOMMENDATIONS

APPROACH

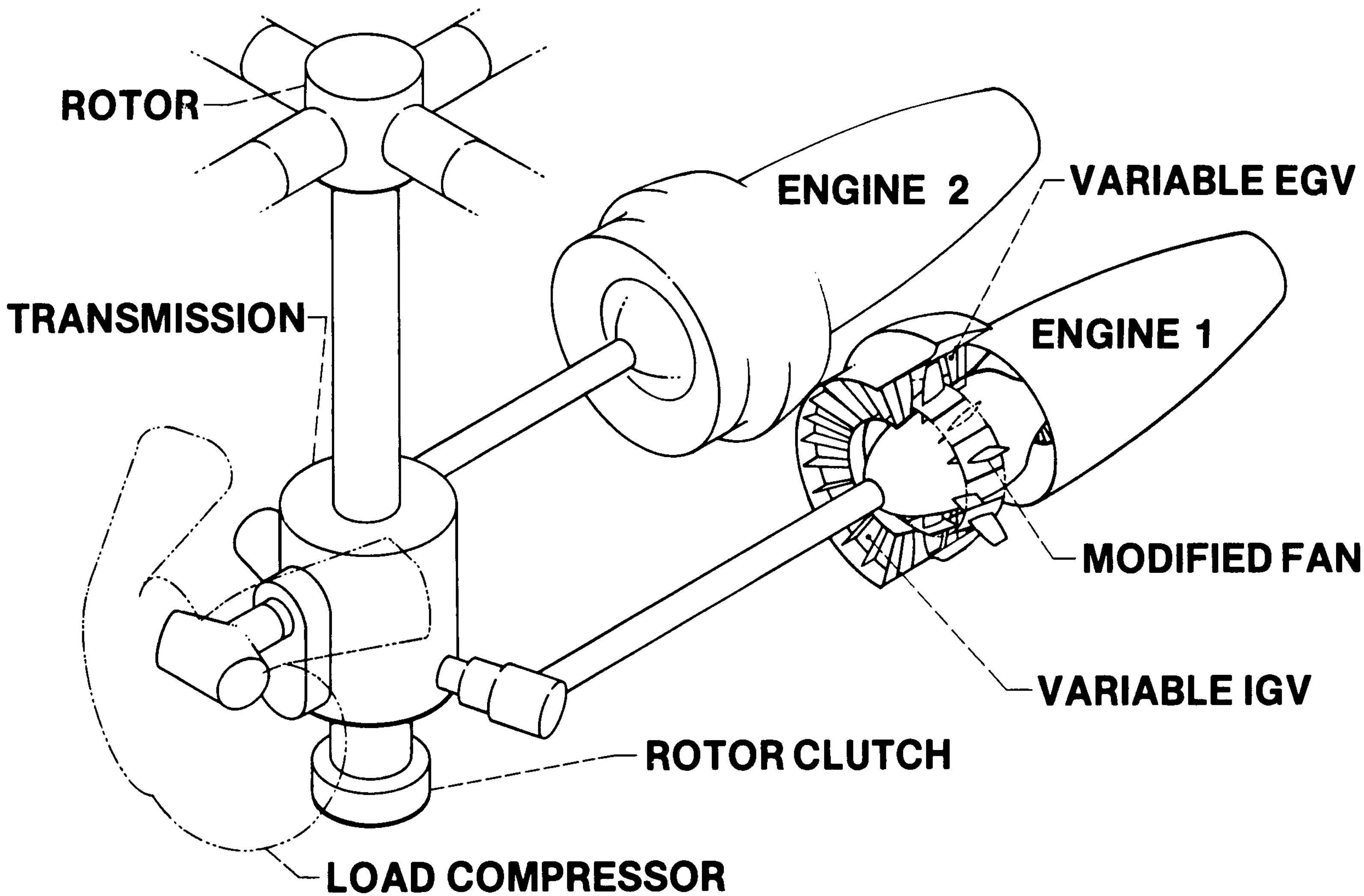
TWO ENGINE CO. CONTRACTS WITH THREE AIRFRAME SUBS.

STATUS

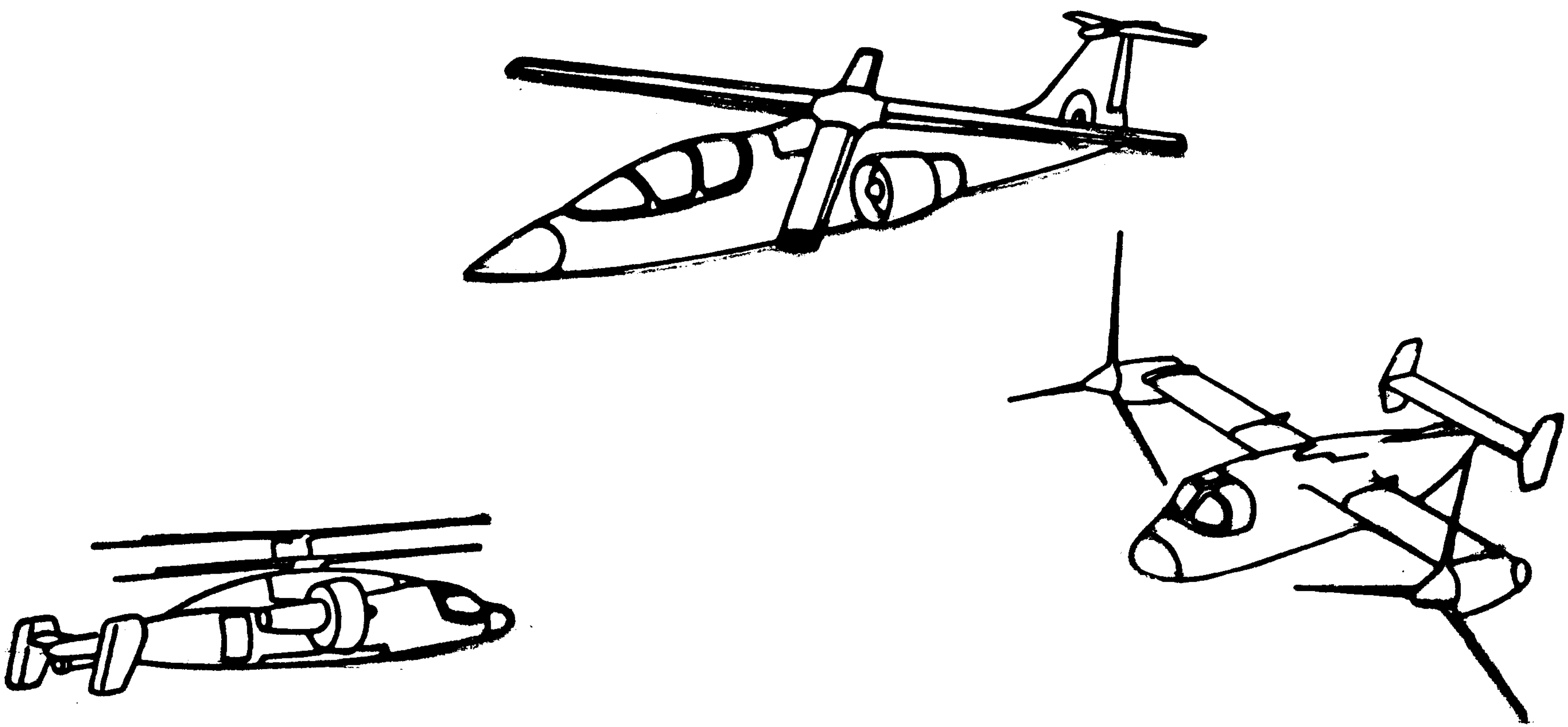
CONTRACT AWARDS EXPECTED NOVEMBER 15, 1980

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LEWIS RESEARCH CENTER

CONVERTIBLE ENGINE PROPULSION SYSTEM



HIGH SPEED ROTORCRAFT



PROPULSION

EXECUTIVE SUMMARY OF ROTORCRAFT PROGRAMS

(NARRATIVE)

HIGH SPEED ROTORCRAFT

MAJOR TASK	DESCRIPTION	CONTACTS/RTOP
CONVERTIBLE ENGINE SYSTEM TECH.	EVALUATE A CONVERTIBLE ENGINE CONCEPT USING VARIABLE INLET AND EXIT GUIDE VANES TO TRANSFER FAN THRUST TO SHAFT HORSEPOWER BOTH STATICALLY AND DYNAMICALLY. A TURBOFAN ENGINE WILL BE MODIFIED TO A CONVERTIBLE ENGINE AND DIGITAL CONTROLS DESIGNED AND INSTALLED UNDER CONTRACT. ENGINE TESTING WILL BE AT LERC. A JOINT NASA-DARPA PROGRAM APPLICABLE TO HIGH SPEED ROTORCRAFT AND VTOL.	R. KOENIG ROTORCRAFT PROP. PROGRAM OFFICE/LERC 6604/532-06-12

JOINT PROGRAM - NASA/DARPA

MEMORANDUM OF UNDERSTANDING

SIGNED BY DR. R. FOSSUM, DR. A. LOVELACE

NOVEMBER 1980

National Aeronautics and
Space Administration
Lewis Research Center

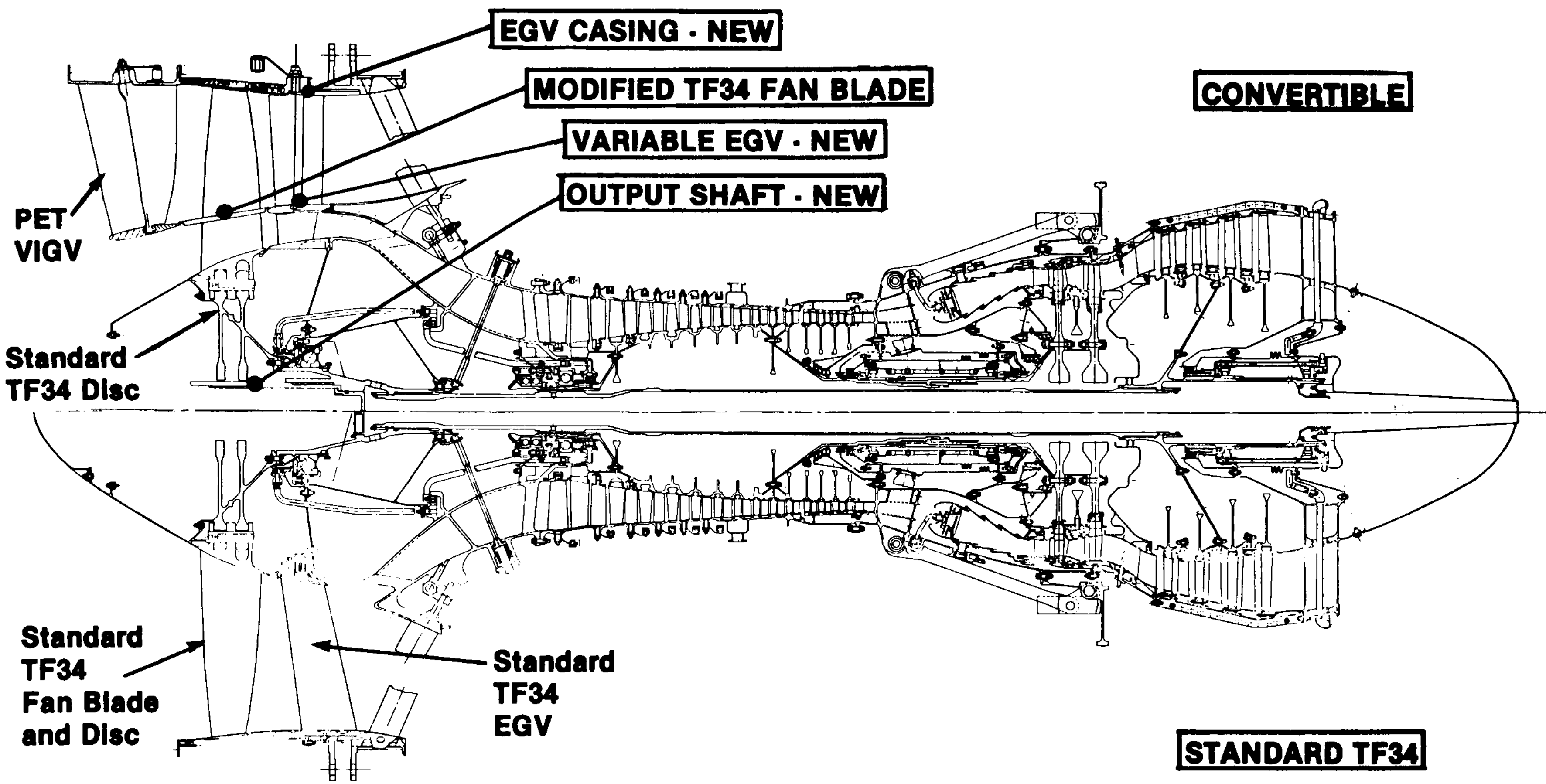
CONVERTIBLE ENGINE SYSTEM TECHNOLOGY

NASA

OBJECTIVE: TO PROVIDE A RESEARCH TOOL AND TO DETERMINE A CONVERTIBLE ENGINE CONCEPT FEASIBILITY BY:

- MODIFICATION OF A BASIC TF-34 TO A CONVERTIBLE ENGINE
- OBTAIN AERO AND OPERATIONAL DATA OF VARIABLE IGV AND EGV'S
- PARTIAL POWER FLOW MATCHING BY CONTROLLED CORE AIR BLEED
- CONTROL TECHNOLOGY FOR DYNAMIC TRANSIENT POWER TRANSFER (FAN TO SHAFT-SHAFT TO FAN)
- APPLICABILITY INCLUDES: "X-WING", ABC, FOLDED TILT ROTOR, COMPOUND AND VTOL

Modified TF34 Fan Configuration



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Space Administration
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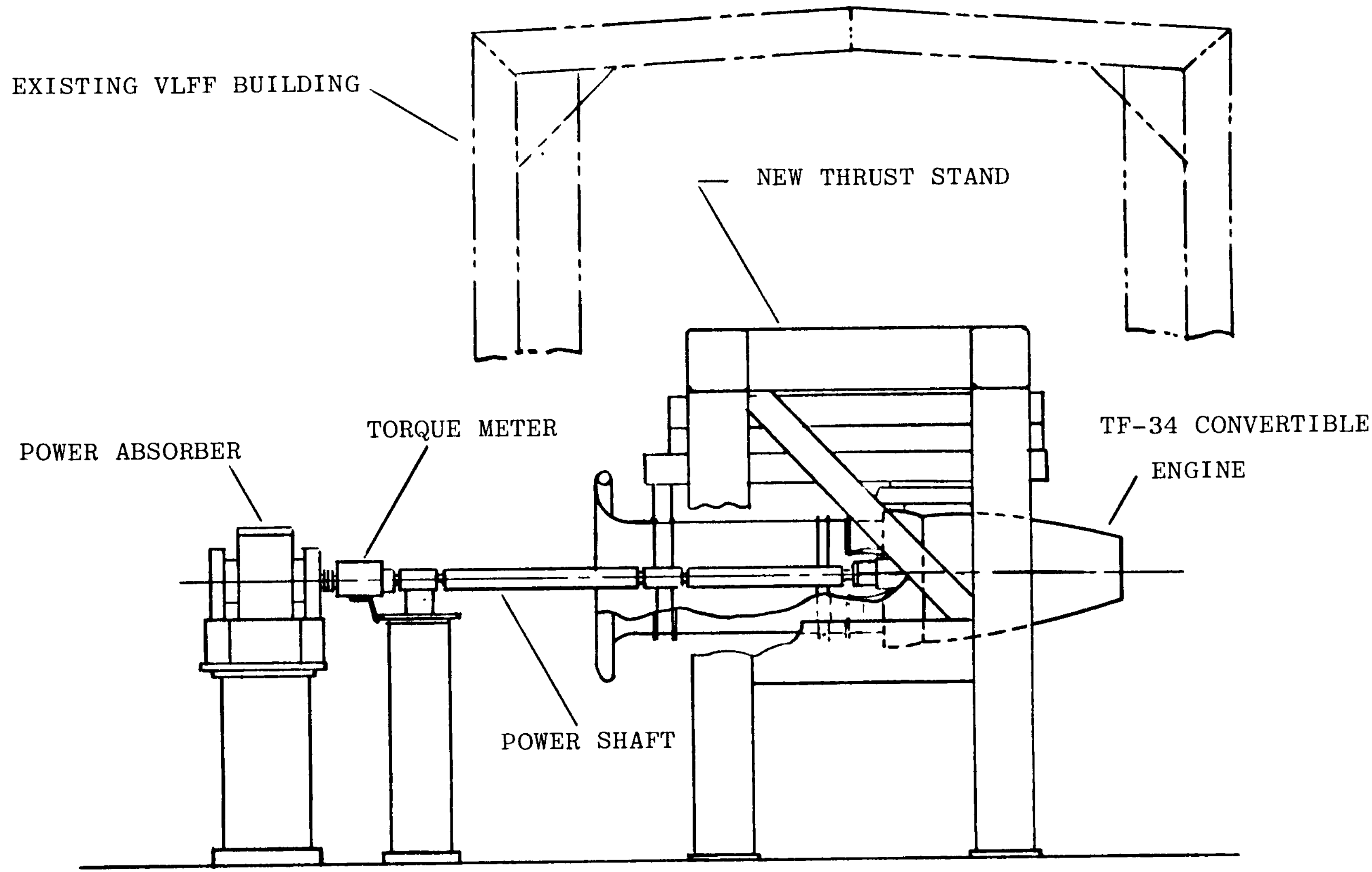
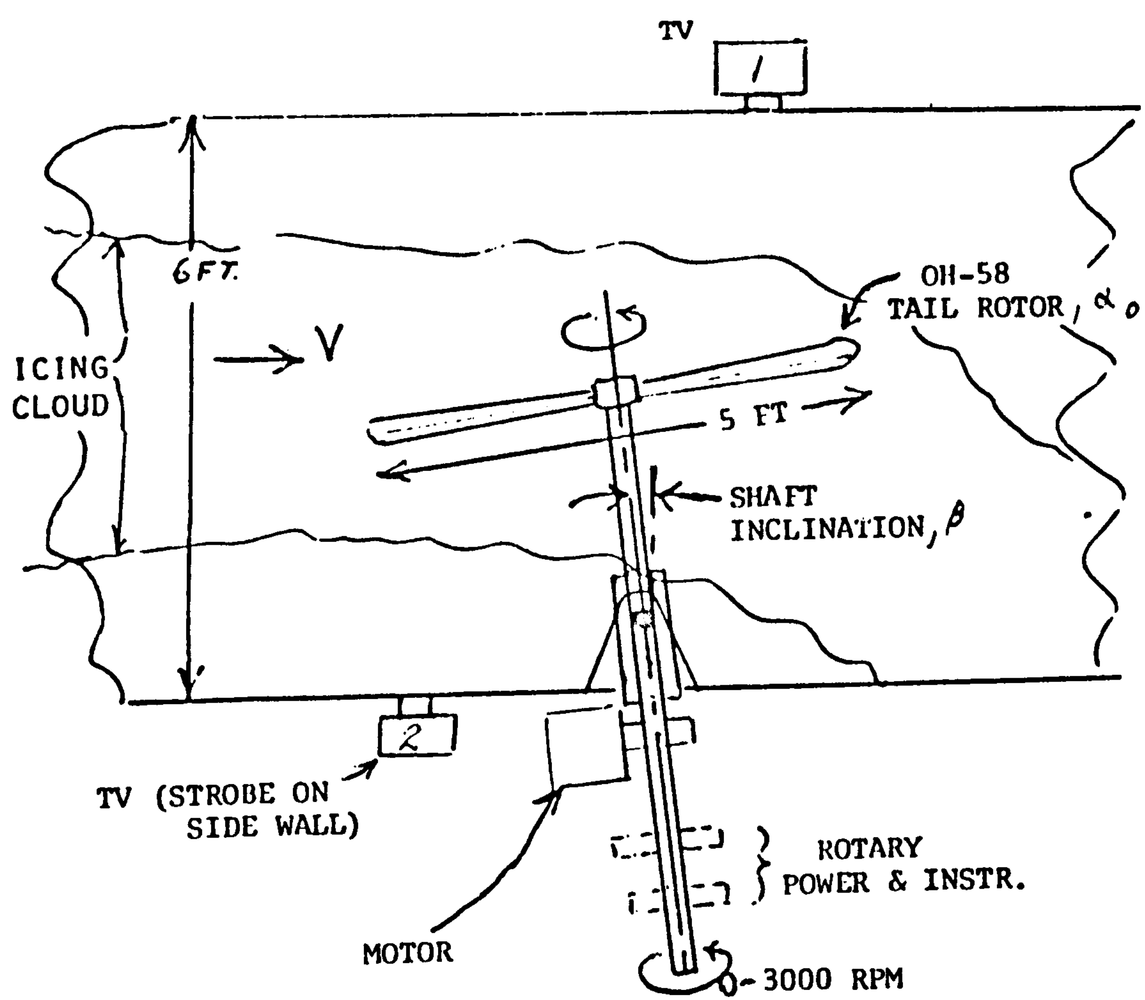
CONVERTIBLE ENGINE INSTALLATION IN MODIFIED VERTICAL LIFT FAN FACILITY



ALL WEATHER SYSTEMS
EXECUTIVE SUMMARY OF ROTORCRAFT PROGRAMS
(NARRATIVE)

MAJOR TASK	DESCRIPTION	CONTACTS/RTOP
ICING:	EXTEND AND UPDATE ANALYSIS CODES FOR ICE SHAPE MODELING, DROPLET TRAJECTORIES AND AERODYNAMIC PENALTIES OF ROTOR SYSTEMS, INTERACTIONS AND ENGINE INLETS. CONDUCT EXPERIMENTS TO VERIFY CODES. DEVELOP RESEARCH MODELS AND EXAMINE NEW OPTIMIZED ICE PROTECTION CONCEPTS SUCH AS ELECTROTHERMAL, PNEUMATIC BOOTS, ICE PHOBICS, FREEZING POINT DEPRESSANTS, IMPULSE, DEFLECTION VIBRATION AND SONIC. TEST TO FULL SCALE PROMISING CONCEPTS. UPDATE FACILITIES. SUPPORT ARC PNEUMATIC DEICER BOOT PROGRAM.	J. REINMANN/SAFETY TECH SEC/LERC 5542/505-44-12, 532-06-12

APPARATUS FOR ROTATING BLADE ICING TESTS (ARBIT) IN NASA IRT



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ALL WEATHER SYSTEMS
EXECUTIVE SUMMARY OF ROTORCRAFT PROGRAMS
(NARRATIVE)

MAJOR TASK	DESCRIPTION	CONTACTS/RTOP
CONTINGENCY POWER:	EXPLORE ECONOMIC PENALTIES AND FEASIBILITY OF EMERGENCY POWER FOR ADVANCED PROPULSION SYSTEMS BY INCORPORATION INTO INITIAL ENGINE DESIGN. INVESTIGATE "BURN OUT POWER" REQUIREMENTS AND CERTIFICATION METHODS.	R. KOENIG ROTORCRAFT PROP. OFFICE LERC/6604

VERY LARGE ROTORCRAFT
EXECUTIVE SUMMARY OF ROTORCRAFT PROGRAMS
(NARRATIVE)

MAJOR TASK	DESCRIPTION	CONTACTS/RTOP
VERY LARGE TRANSMISSIONS:	DEVELOP DESIGN TECHNOLOGY FOR HIGH SPEED, HIGH POWER (10,000-25,000 HP), LIGHTWEIGHT GEARS BY INSTRUMENTATION AND TEST OF EXISTING HLH MODIFIED HARDWARE. USE DATA TO VERIFY A NEWLY DEVELOPED FINITE ELEMENT MODEL DESIGN CODE FOR GEAR DESIGN.	N. SAMANICH TURBINE ENGINE BR/LERC 6604/532-06-12

SYSTEMS INTEGRATION
ADVANCED ENGINES

KEY TECHNOLOGY TASK AREAS	GOALS
ADVANCED COMPONENTS/ ENGINE VERIFICATION	PROVIDE "PROOF-OF-CONCEPT" IN REAL WORLD ENVIRONMENT
UNCONVENTIONAL COMPONENTS/ ENGINE VERIFICATION	DEMONSTRATE STATE OF READINESS OF ADVANCED TECHNOLOGY COMPONENTS

REQUIREMENTS FOR EFFICIENT SMALL TURBINE ENGINES

TAKING UP THE CHALLENGE

By Rodney Taylor (Hughes Helicopter)

Aircraft development depends on availability of engines of the proper size and rating to do the required job. Commerical helicopter development in the past consisted of converting a military machine to civilian use. Today's military helicopter is not suitable as use as a commercial machine. Since most engines are designed for use in military machines, some commercial market segments go begging for want of a proper helicopter to do the job. Two significant examples are the 2-3 place single engine trainer and a light weight efficient 6 place executive twin. Although these machines could use a common 300 SHP turbine none exist. With fuel cost and availability worsening at an alarming rate, light weight efficient machines are where the development should be concentrated. Technology and market are available to develop the required engines. It simple awaits the acceptance of the challenge.

HAA/NASA ADVANCED ROTORCRAFT TECHNOLOGY WORKSHOP

BY DR. KENNETH M. ROSEN (SIKORSKY AIRCRAFT)

NASA's Advanced Rotorcraft Technology Program presents the opportunity to investigate some of the problems facing helicopter manufacturers today. The areas in which the program can provide assistance relative to Propulsion Systems form the subject of this viewgraph presentation to the Propulsion Session of the HAA/NASA Advanced Rotorcraft Technology Workshop.

Sikorsky believes NASA's Rotorcraft Technology Program should include several specific efforts relative to Propulsion Systems. These efforts include the areas of helicopter icing, engine controls, bleed air management and transmission technology and noise reduction. Each of these areas is discussed individually with an outline of the problem and the suggested ways in which NASA can contribute to its solution.

Helicopter icing is an area in which significant contributions can be made in providing the data base for revising current certification requirements. R&D efforts should also be conducted to define the icing environment at low altitudes, to improve icing development facilities, to correlate natural and simulated icing, and to develop falling and blowing snow test facilities.

The development of electronic fuel controls for helicopter engines presents the opportunity to integrate the engine and aircraft control systems to a greater degree than heretofore possible. New modeling technology and the capability of information exchange between the two sys-

tems can improve engine dynamic response and minimize rotor droop while avoiding instabilities. Studies directed at identifying the airframe parameters that could be interfaced with the engine control could lead to improved aircraft performance and maximum utilization of the new control technology.

With the increased use of engine bleed air on modern helicopters, it has become increasingly important to manage the bleed air supply to minimize aircraft power penalties. An approach to bleed management that warrants study utilizes mixing of mid and final stage compressor bleed air to use the minimum amount of bleed at the optimum bleed temperature as a function of ambient temperature and engine power.

Gearbox noise reduction is an area of increasing importance in the civil helicopter field and NASA's technology program should include efforts to establish effective means for predicting and controlling transmission noise. Noise will be a strong consideration in new designs with transmission weight goals likely to be inconsistent with noise goals. It is important, therefore, that a systems approach be taken to achieve noise reduction recognizing the reduction in helicopter weight afforded by a gearbox noise reduction. Some of the concepts which are being considered for achieving noise reduction include high contact ratio gears, transmission housing damping, and acoustic isolation of the transmission. Coupled with a dynamic analysis of the power train design, these and other concepts could provide significant transmission noise reductions in future designs.

HELICOPTER ICING CERTIFICATION IS A MAJOR CHALLENGE FOR THE 1980'S

- PRESENT RULES EFFECTIVELY PRECLUDE CERTIFICATION.
- SIGNIFICANT R & D EFFORT IS REQUIRED
  - DEFINE ICING ENVIRONMENT
  - VALIDATE CERTIFICATION TOOLS

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HELICOPTER ICING R&D REQUIREMENTS

- DEFINITION OF ICING ENVIRONMENT AT LOW ALTITUDES
- IMPROVED DEVELOPMENT FACILITIES
  - NEED FOR IMPROVED HELICOPTER SPRAY TANKER, ICING TUNNELS, AND HOVER SPRAY RIG
    - LARGER TEST SECTIONS - NASA
    - INCREASED RANGE OF ICING PARAMETERS - NASA
- CORRELATION BETWEEN NATURAL & SIMULATED ICING
  - VALIDATION OF SCALED MODEL TECHNIQUES - NASA
  - FLIGHT TEST USING MODERN HELICOPTER
  - IMPROVE HOVER TO FORWARD FLIGHT DATA EXTRAPOLATION
  - VALIDATION OF SIMULATED ICING TESTING TO MINIMIZE NATURAL ICING TESTS
  - SIMULATOR DEVELOPMENT TO PREDICT EFFECTS OF ICING - NASA
- FALLING AND BLOWING SNOW
  - DEVELOPMENT OF ADVISORY CIRCULAR
  - DEFINITION OF SNOW TEST FACILITY

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LOW ALTITUDE ICING ENVIRONMENT MUST BE DEFINED FOR HELICOPTERS

IMPROVED DEFINITION OF ICING ENVIRONMENT THROUGH THE USE OF

- FLIGHT TEST PROGRAM
- NASA ANALYSIS OF DATA BASE

- INCORPORATE INTO REVISED REQ'T FOR HELICOPTER CERTIFICATION

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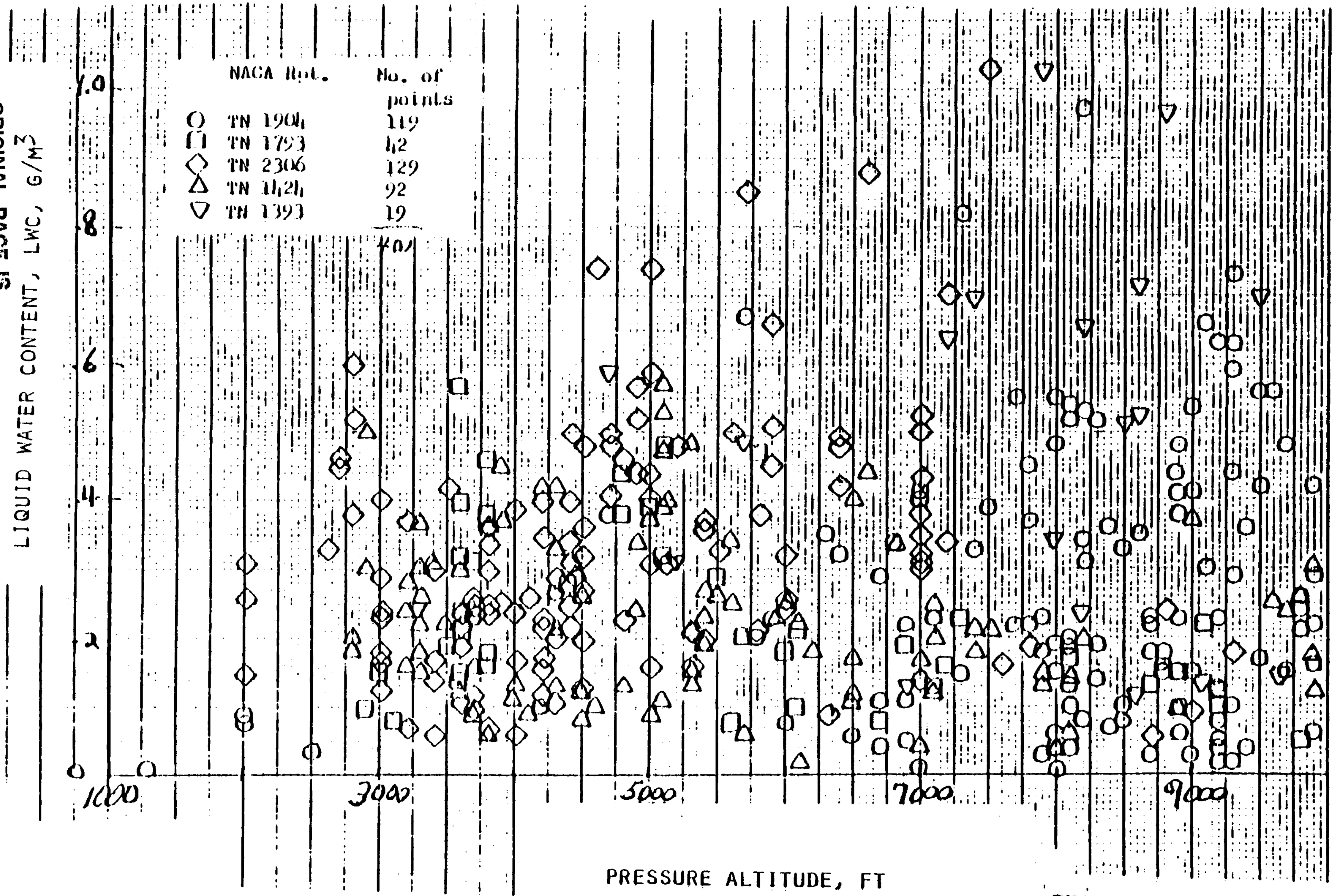
OLD NACA ICING CLOUD DATA FOR LWC AT LOW ALTITUDES: DATA TAKEN DURING ICING CLOUD SURVEY FLIGHTS



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STEPS IN DEVELOPMENT/CERTIFICATION

- LABORATORY-DEVELOPMENT
- HOVER IN ARTIFICIAL ICING-DEVELOPMENT
- FORWARD FLIGHT IN ARTIFICIAL ICING-DEVELOPMENT/CERTIFICATION
- FLIGHT IN NATURAL ICING-CERTIFICATION

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ICING LAB FACILITIES

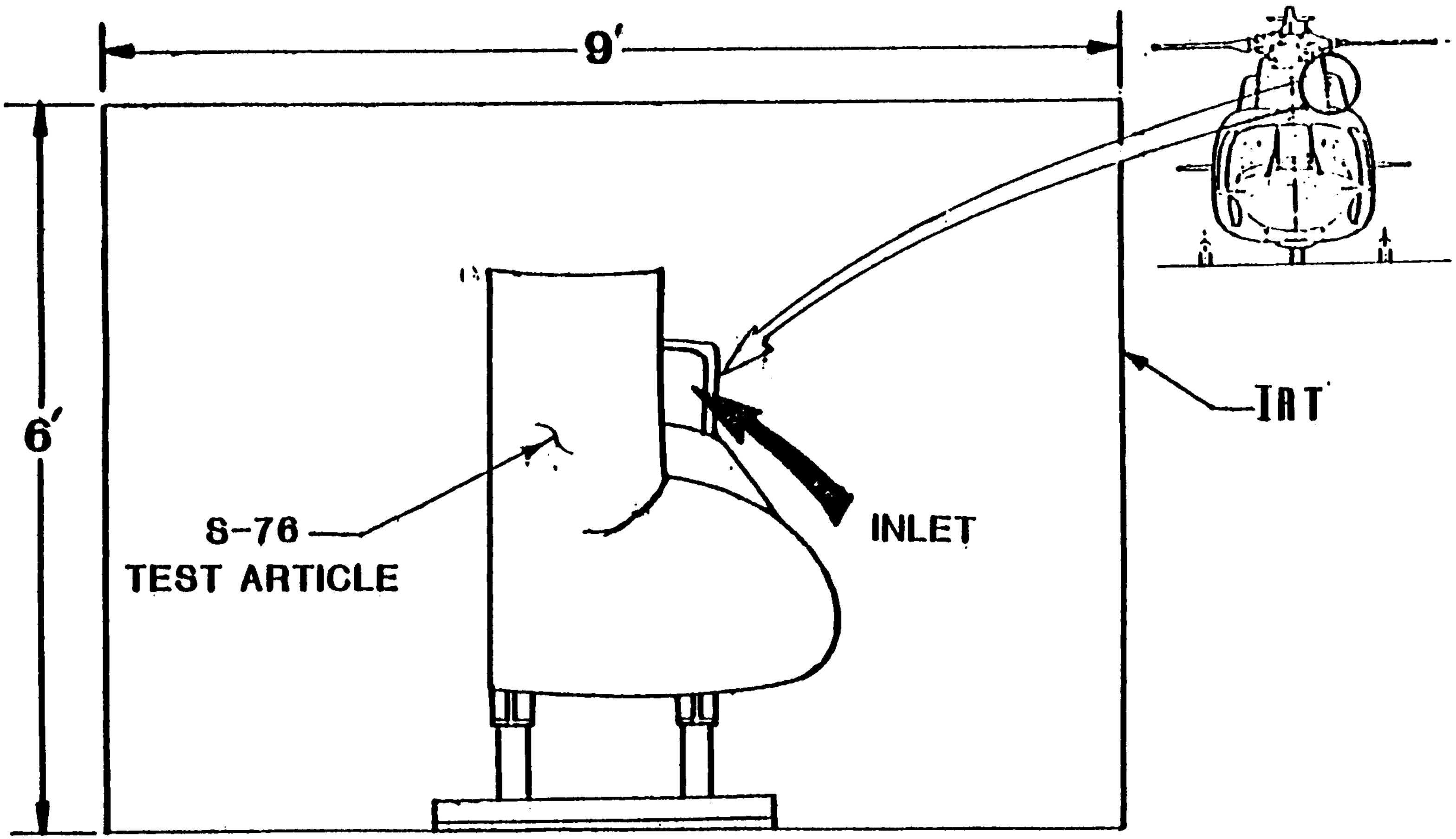
- NASA LEWIS ICING RESEARCH TUNNEL
- USAF ARNOLD RESEARCH CELL (TUNNEL)

INSTALLATION, DEVELOPMENT/ CERTIFICATION

- NRC ENGINE TEST FACILITY
- USN NAPTC ENGINE TEST FACILITY
- USAF ARNOLD ENGINE TEST FACILITY

LABORATORY SIZE RESTRICTIONS

- IRT IS LARGEST FACILITY IN OPERATION



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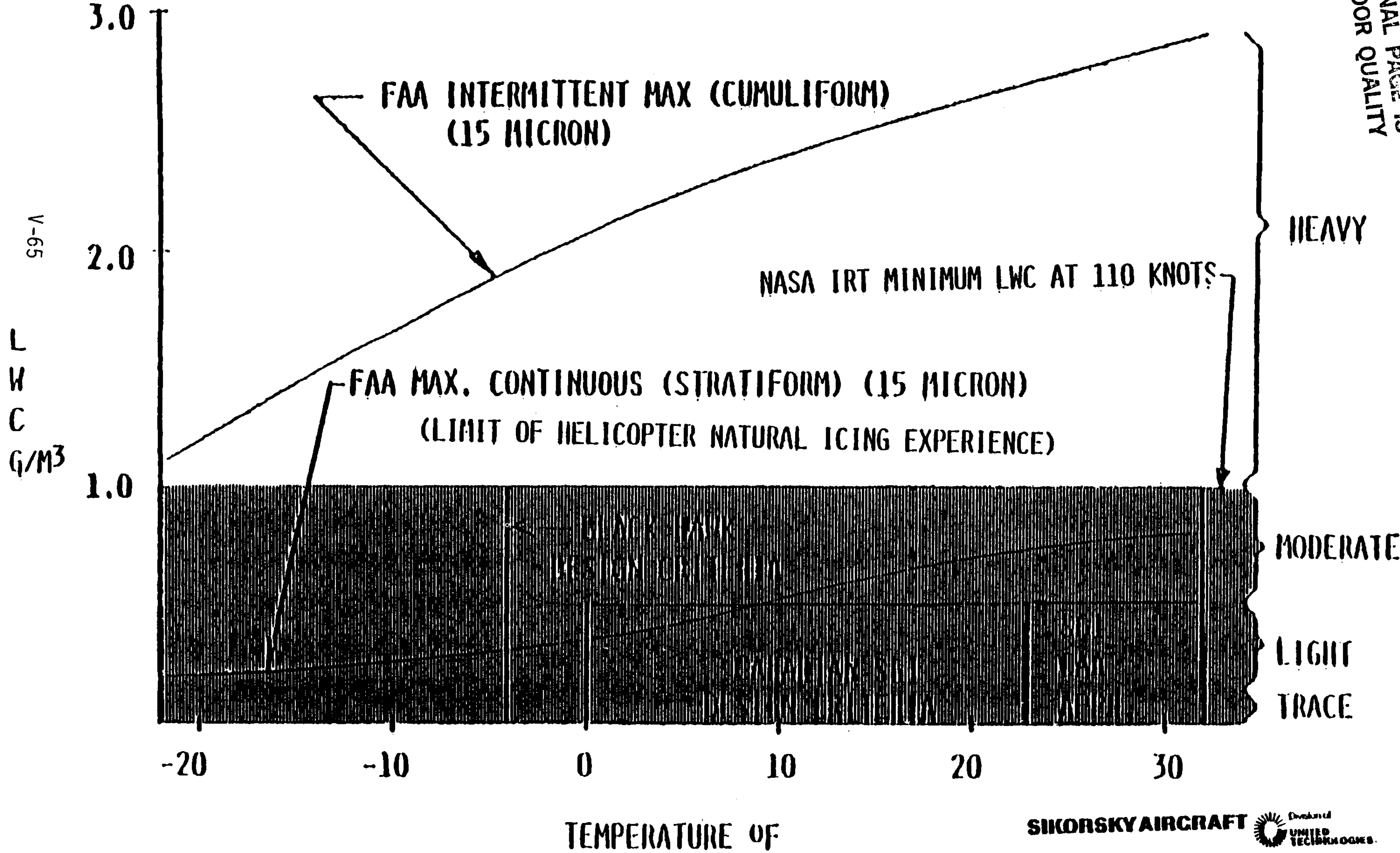
NEED FOR IMPROVED IRT LWC RANGE



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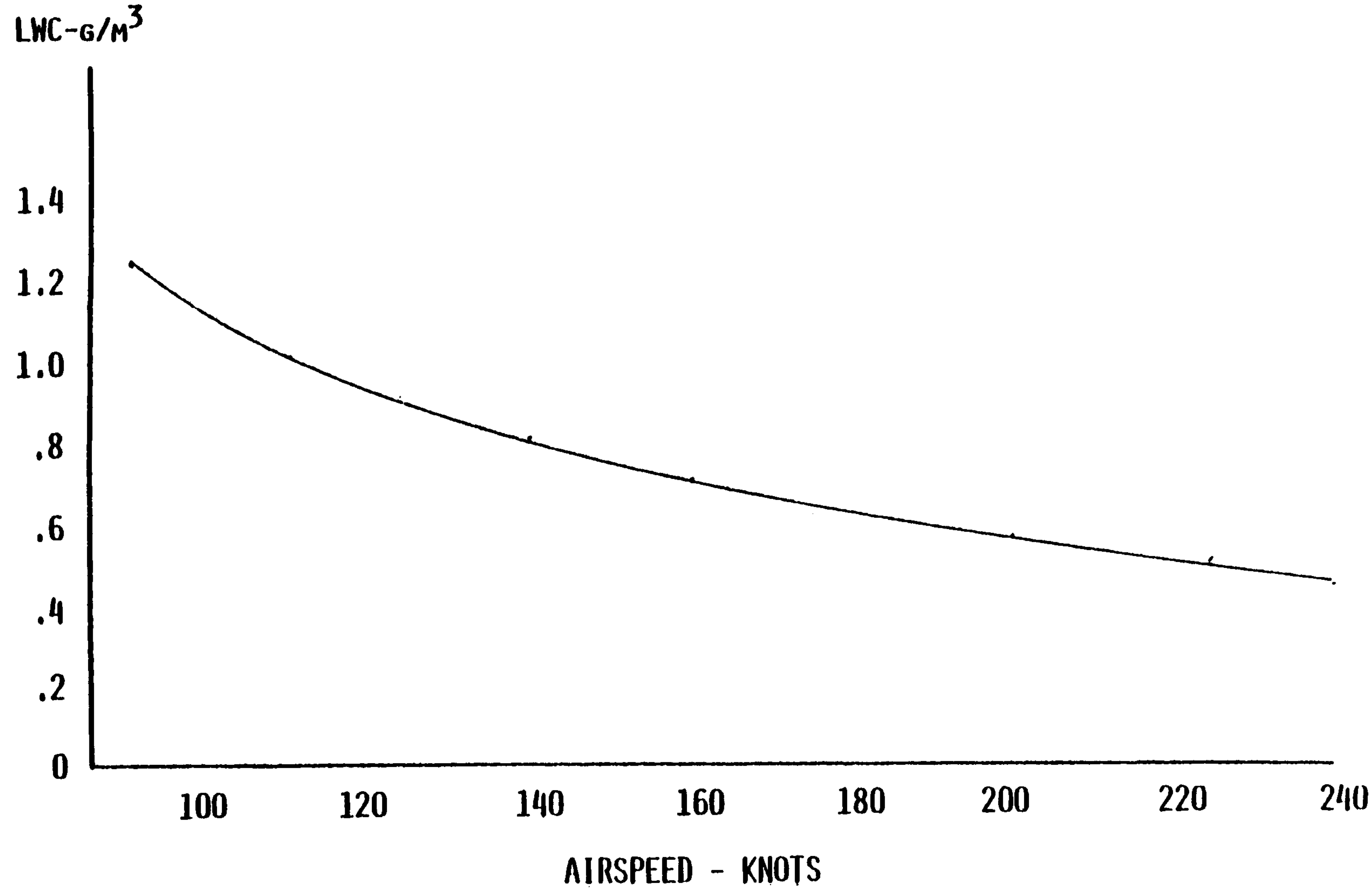
NASA ICING RESEARCH TUNNEL
MINIMUM LWC VS AIRSPEED



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ICING LABORATORY ACTIONS REQUIRED

- IMPROVE ICING SIMULATION
  - LOWER SPEED CAPABILITY
  - INCREASED RANGE OF LWC
  - MODERN LWC AND DROPLET SIZE INSTRUMENTATION

  FOR IRT

- LARGER TEST SECTION
  - IRT - USE OF SECONDARY TEST SECTION ?
  - AWT CONVERSION TO ICING FACILITY
  - PROVISIONS FOR MODEL TESTING?

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VALIDATION OF SCALED MODEL TECHNIQUES

- SHORT TERM: INCREASED USE OF DEVELOPMENT TOOL.
- LONG TERM: CREDIT TOWARD CERTIFICATION.
- METHODOLOGY: CONDUCT MODEL ICING TESTS (ICING TUNNELS) TO CORRELATE WITH DATA FROM NATURAL ICING FLIGHT TESTS.

DEVELOPMENT OF A HYBRID COMPUTER SIMULATOR TO PREDICT IMPACT OF ICING ENVIRONMENT

- USES WIND TUNNEL DATA DEVELOPED AERODYNAMICS AND HANDLING QUALITIES PARAMETERS.
- UPDATE OF AERO AND HANDLING QUALITIES PARAMETERS IN EXISTING AIRCRAFT SIMULATOR SOFTWARE.
- APPLICATION OF THERMAL DE-ICE SOFTWARE MODULE TO SIMULATOR.
- PREDICTION OF AIRCRAFT HANDLING QUALITY RESULTS AND LOADS RESULTING FROM AN ICING EXPOSURE.
- COMPARISON WITH TEST DATA BASE.

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ENGINE/AIRFRAME CONTROL INTEGRATION

- ADVANCED ELECTRONIC FUEL CONTROLS OFFER THE POTENTIAL FOR INCREASED INTERACTION OF AIRCRAFT AND ENGINE CONTROL SYSTEMS.

- INTERACTION OF ENGINE AND AIRCRAFT CONTROLS, IN TURN, PROVIDES AN OPPORTUNITY FOR SIGNIFICANT IMPROVEMENTS IN ENGINE DYNAMIC RESPONSE AND, THEREFORE, IMPROVEMENTS IN AIRCRAFT PERFORMANCE IN SUCH AREAS AS ROTOR DROOP AND DUTCH ROLL.

- TO TAKE ADVANTAGE OF THIS OPPORTUNITY, A STUDY TO DEFINE THE AIRFRAME PARAMETERS THAT COULD BE SUPPLIED TO AN ENGINE CONTROL, AND THE BENEFITS TO BE GAINED THEREFROM, IS REQUIRED.

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INTERACTIVE CONTROLS STUDY

- SELECT A MODERN CIVIL HELICOPTER AS THE BASIS FOR THE STUDY.
- IDENTIFY POTENTIAL BENEFITS IN HELICOPTER PERFORMANCE THAT WOULD RESULT FROM IMPROVED ENGINE RESPONSE.
- IDENTIFY THE AIRCRAFT PARAMETERS THAT COULD BE INTERFACED WITH THE ENGINE CONTROL TO PROVIDE THESE BENEFITS.

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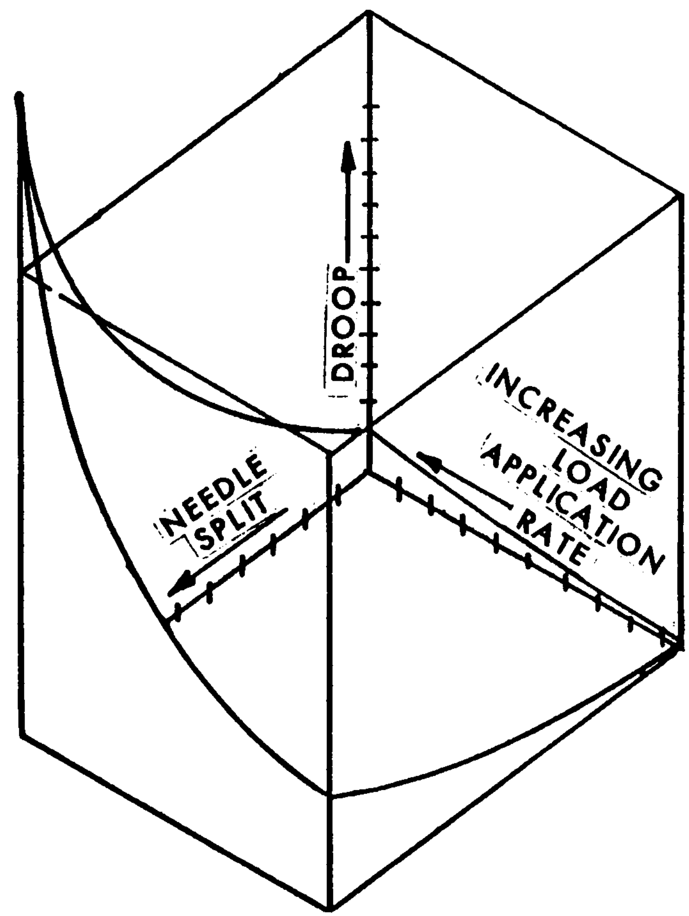
DROOP CUBE



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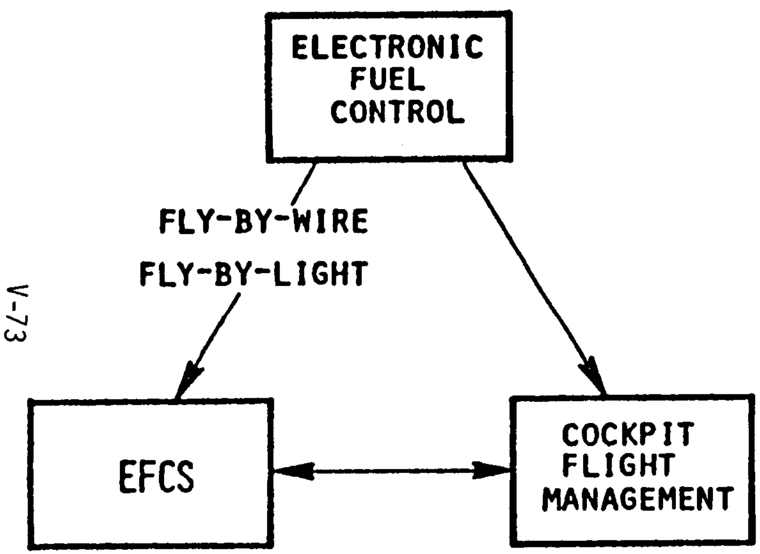
EXPLOIT FULL POTENTIAL OF ELECTRONIC SOLUTION



ENGINES

- RESPONSE ENHANCEMENT
- STABILITY ENHANCEMENT
- ISOCHRONOUS GOVERNING
- TORQUE MATCHING
- START ENHANCEMENT
- SELF LIMITING
- STALL PROTECTION
- OVER SPEED PROTECTION
- AUTO. POWER ASSURANCE

OTHER

- AFCS CROSS TALK
- CONDITIONING MONITORING & DIAGNOSTICS
- INTEGRATED COCKPIT
- COCKPIT FLIGHT MANAGEMENT

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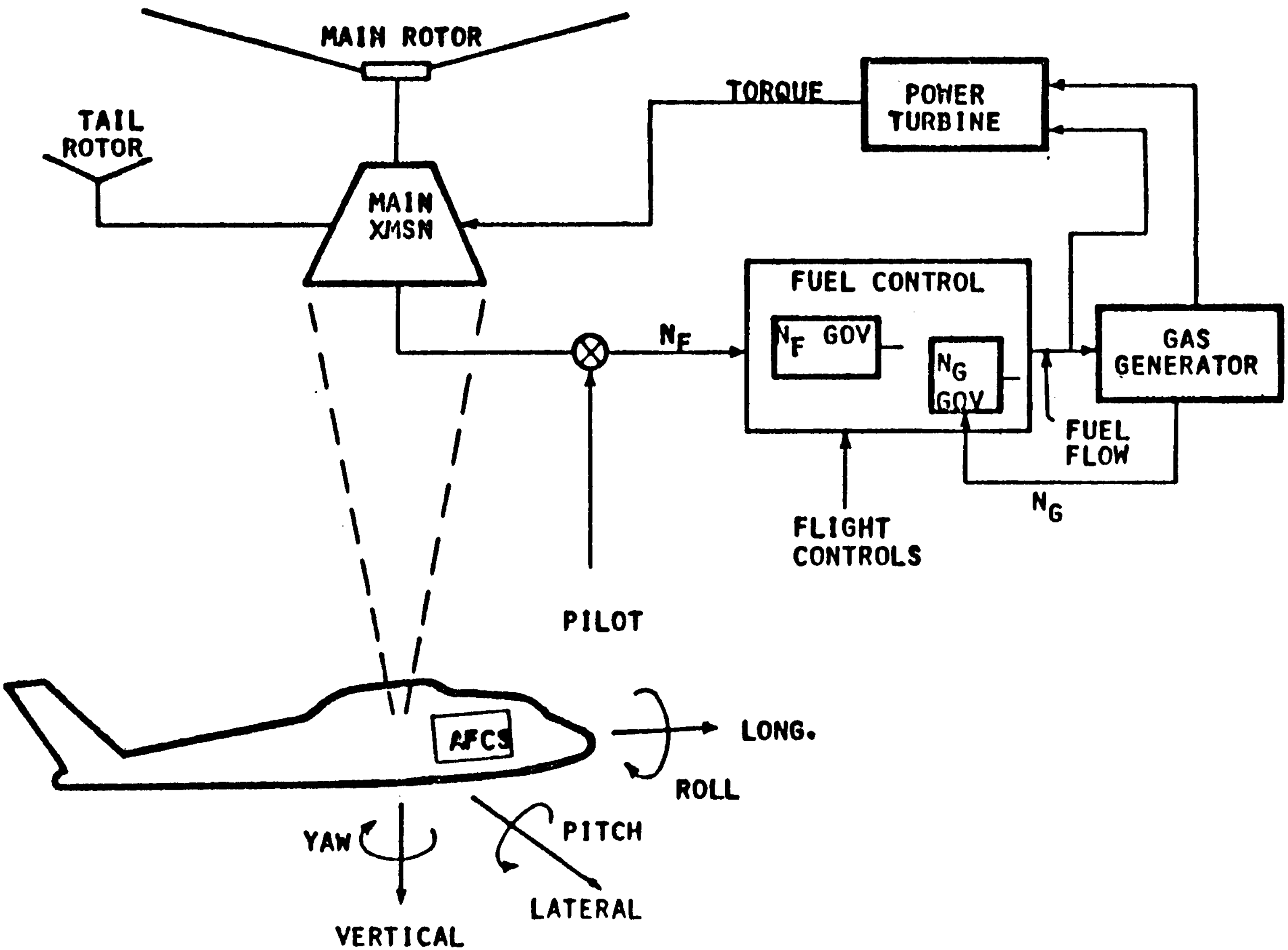
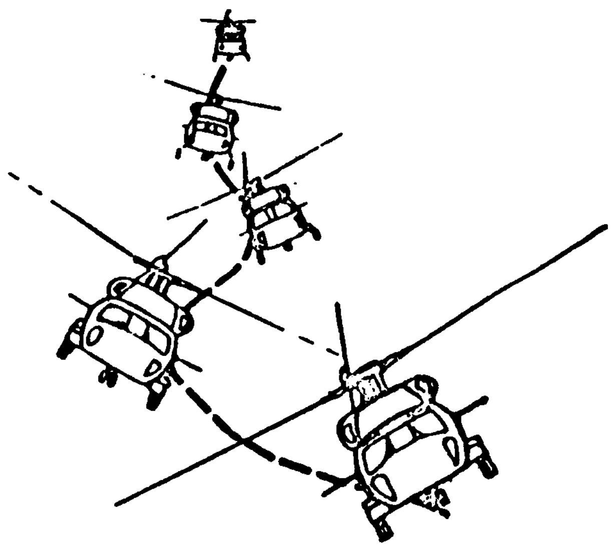
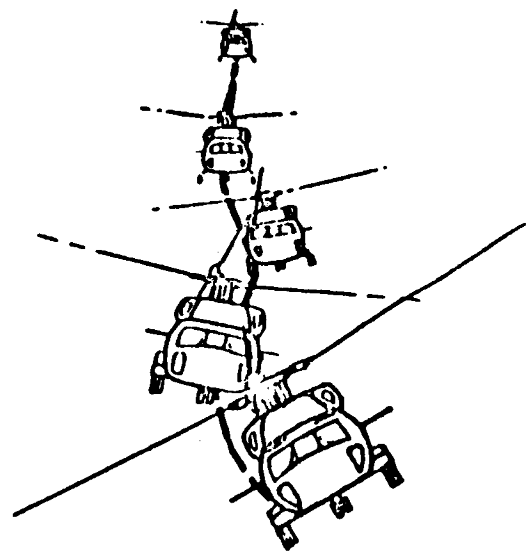
SYSTEM SIMULATION



CLASSIC AIRPLANE DUTCH ROLL
INFLUENCED BY FUEL MANAGEMENT DYNAMICS



ADVERSE FUEL CONTROL COUPLING



ZERO FUEL CONTROL INTERACTIONS

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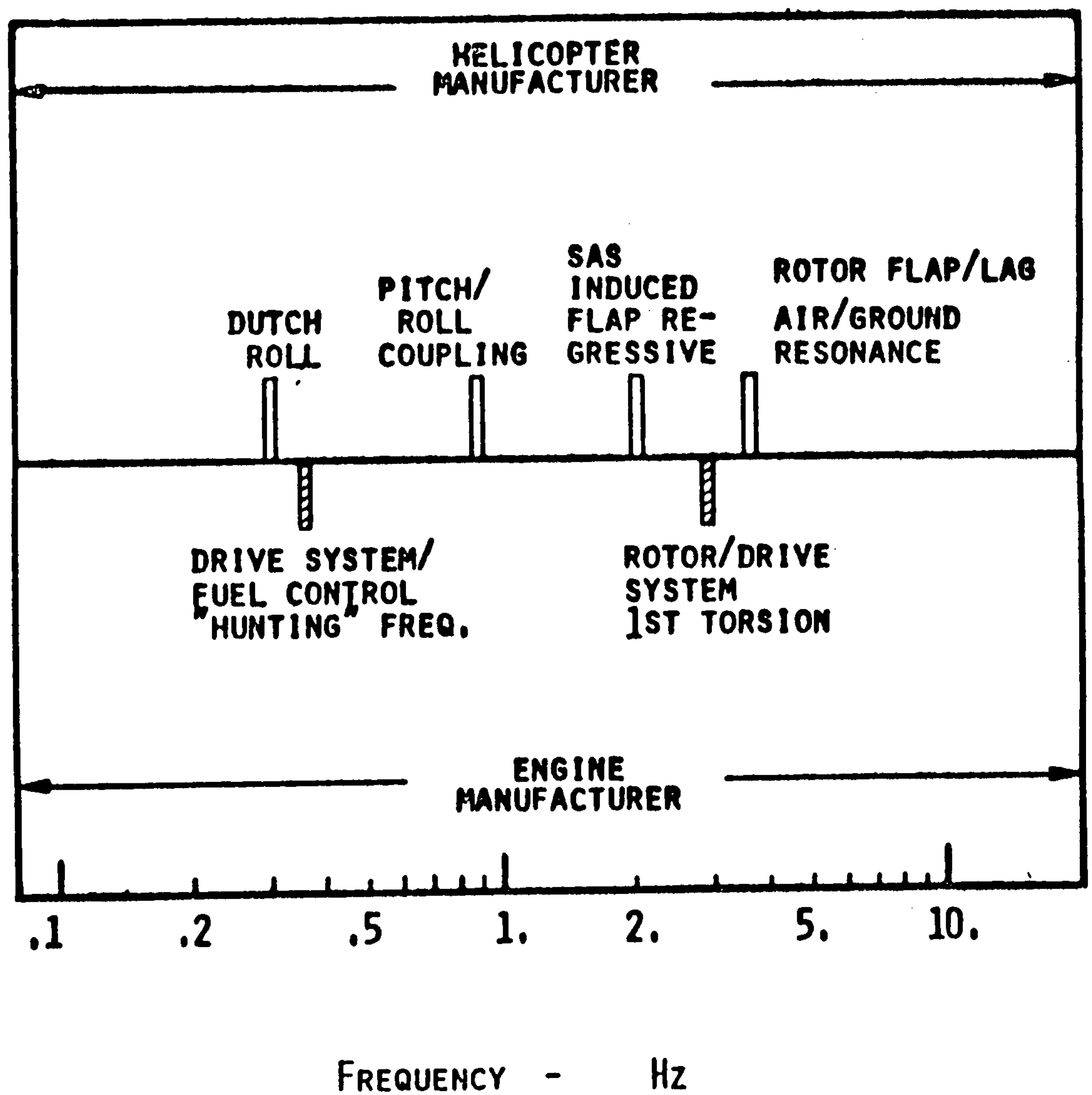
SYSTEM MODES



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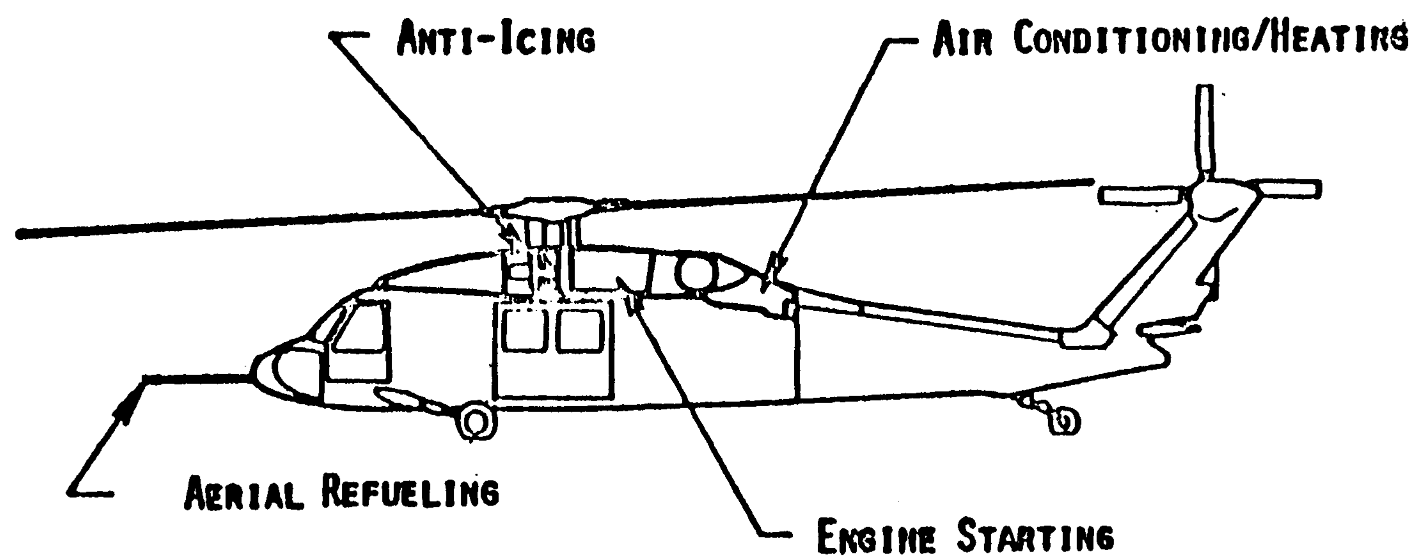
BLEED AIR MANAGEMENT

- ENGINE BLEED AIR IS FINDING AN INCREASING NUMBER OF APPLICATIONS ON MODERN HELICOPTERS.

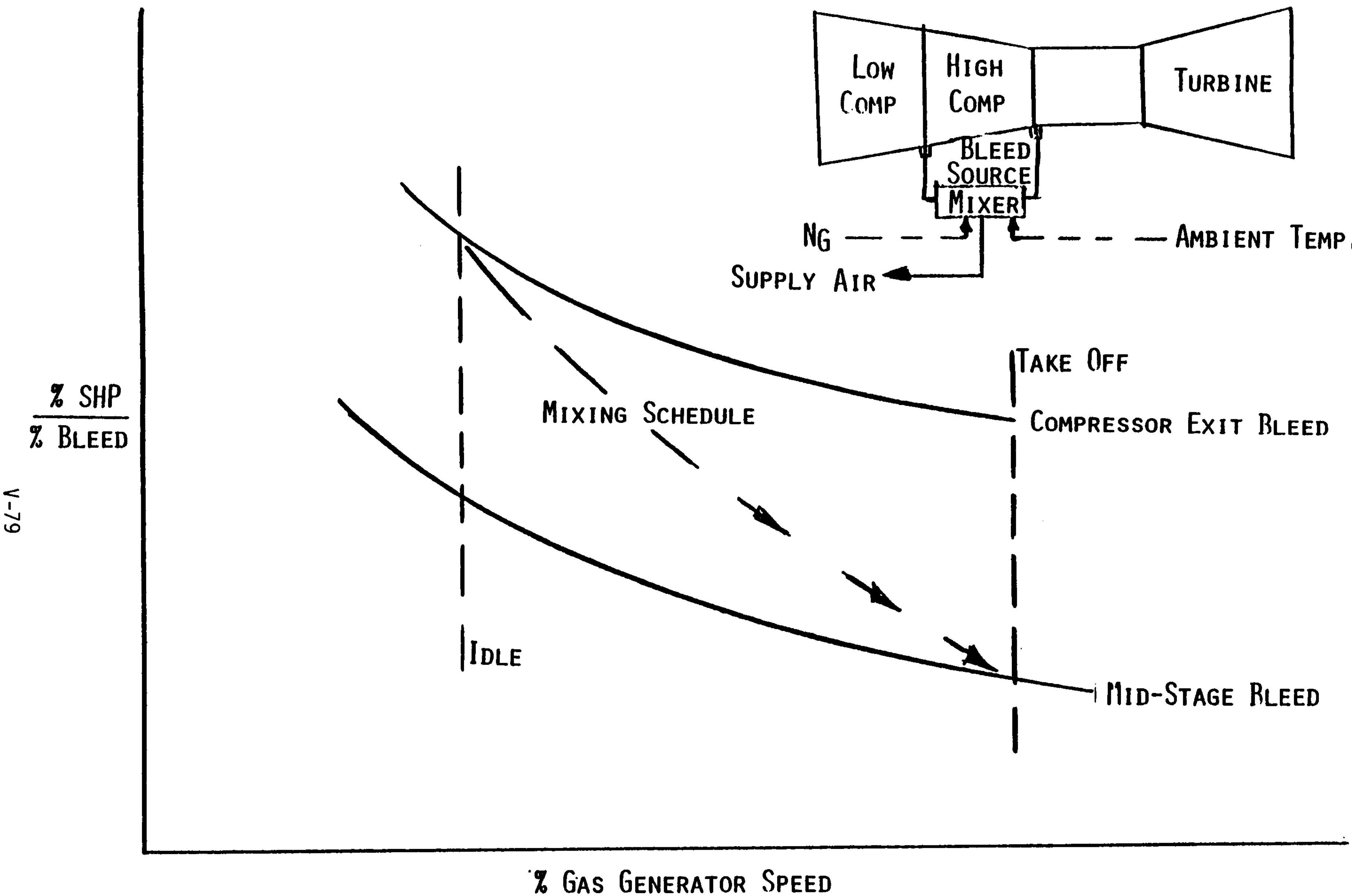
- SIGNIFICANT PENALTIES IN POWER AVAILABLE ASSOCIATED WITH ENGINE BLEED REQUIRE THAT BLEED EXTRACTION BE LIMITED TO PROVIDING THE MINIMUM ENERGY REQUIRED.

- ENGINE BLEED PRESSURE AND TEMPERATURE SHOULD BE MATCHED AS CLOSELY AS POSSIBLE TO THE REQUIREMENTS TO MINIMIZE POWER PENALTIES.

BLEED AIR USAGE IS INCREASING ON MODERN HELICOPTERS



A BLEED AIR MANAGEMENT SYSTEM WILL REDUCE SYSTEM PENALTIES



NOISE REDUCTION IS KEY TRANSMISSION TECHNOLOGY ATTRIBUTE

- EMPHASIS IN 1980'S MUST BE DECIDED BY SYSTEM PAYOFF.
- PRINCIPAL SYSTEM PAYOFFS RESULT FROM NOISE REDUCTIONS, IMPROVED R&M, REDUCED WEIGHT.
- NOISE REDUCTION PAYOFFS ARE SO LARGE THAT NOISE MUST BE GIVEN STRONG CONSIDERATION IN NEW DESIGNS.
- NOISE REDUCTION GOALS ARE CONSISTENT WITH EFFICIENCY AND R&M GOALS.
- TRANSMISSION WEIGHT REDUCTION GOALS ARE LIKELY TO BE INCONSISTENT WITH NOISE GOALS.
- THE TECHNOLOGY FOR PREDICTING AND CONTROLLING NOISE OF A TRANSMISSION HAS NOT BEEN QUANTIFIED.

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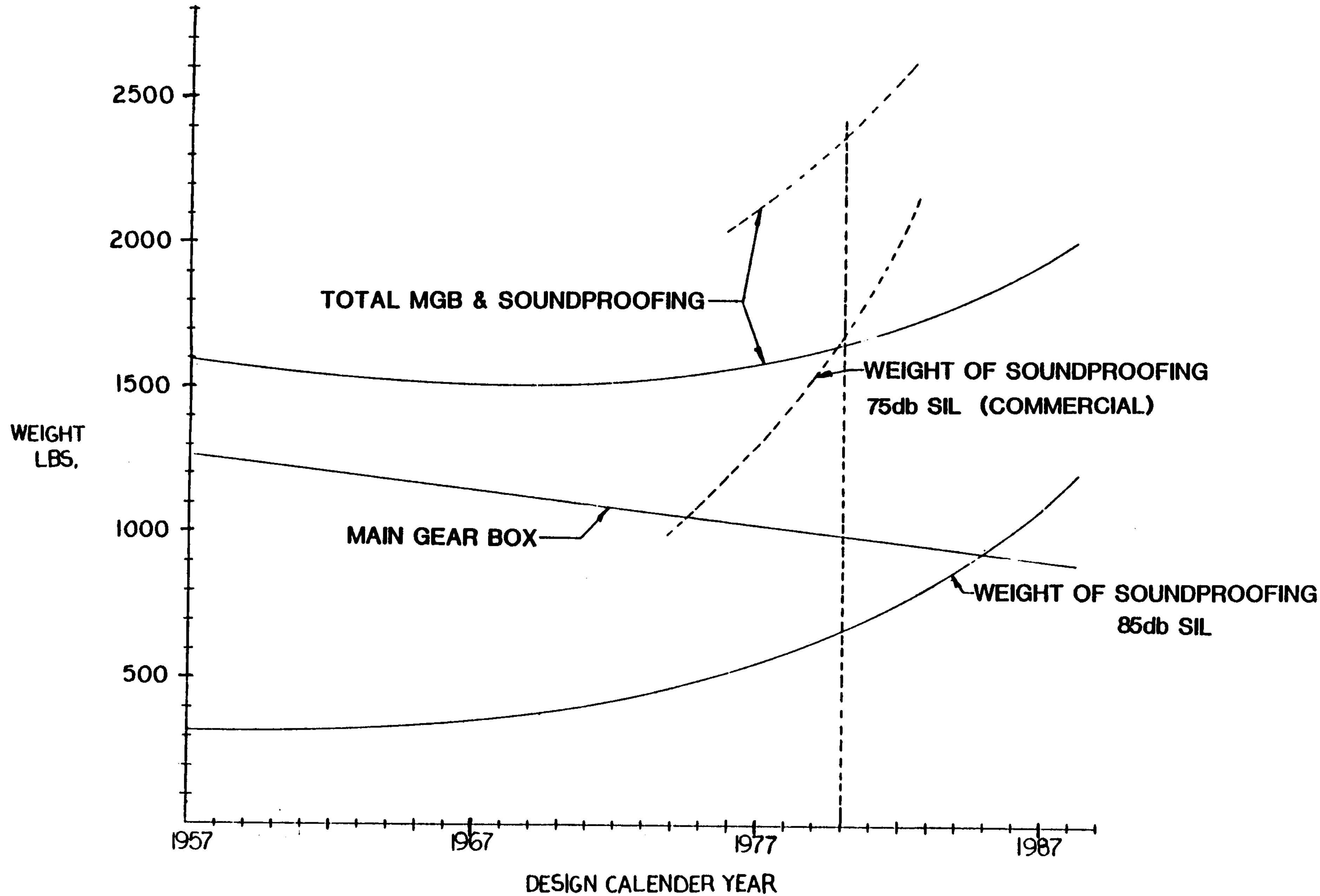
GEAR BOX WEIGHT TECHNOLOGY GAIN OFFSET BY ACOUSTIC TREATMENT WEIGHT PENALTY



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CONCEPTS FOR ACHIEVING TRANSMISSION ATTRIBUTE IMPROVEMENT

Concept	Improvement		
	Weight	R&M	Noise
HCR Gears			X
Isolated Ring Gear			X
Gear Phasing			X
Gear Damping			X
Tooth Profile			X
Case Damping			X
Couplings		X	
High Speed Clutch	X	X	
Integral Shaft/Bevel Gears	X	X	
Bearings	X	X	
Metal Matrix Housing	X	X	
Composite Drive Shafts	X	X	
Dynamic Compaction of Powdered Metal	X	X	X

TRANSMISSION NOISE SIGNATURE REDUCTION CAN BE DEMONSTRATED TECHNOLOGY IN 1980'S

• POWER TRAIN DESIGN - DYNAMIC ANALYSIS	3 DB
• PLANETARY GEAR PHASING	2 DB
• GEAR WEB & HOUSING DAMPING	5 DB
• ACOUSTIC TRANSMISSION ISOLATION	8 DB
	-18 DB

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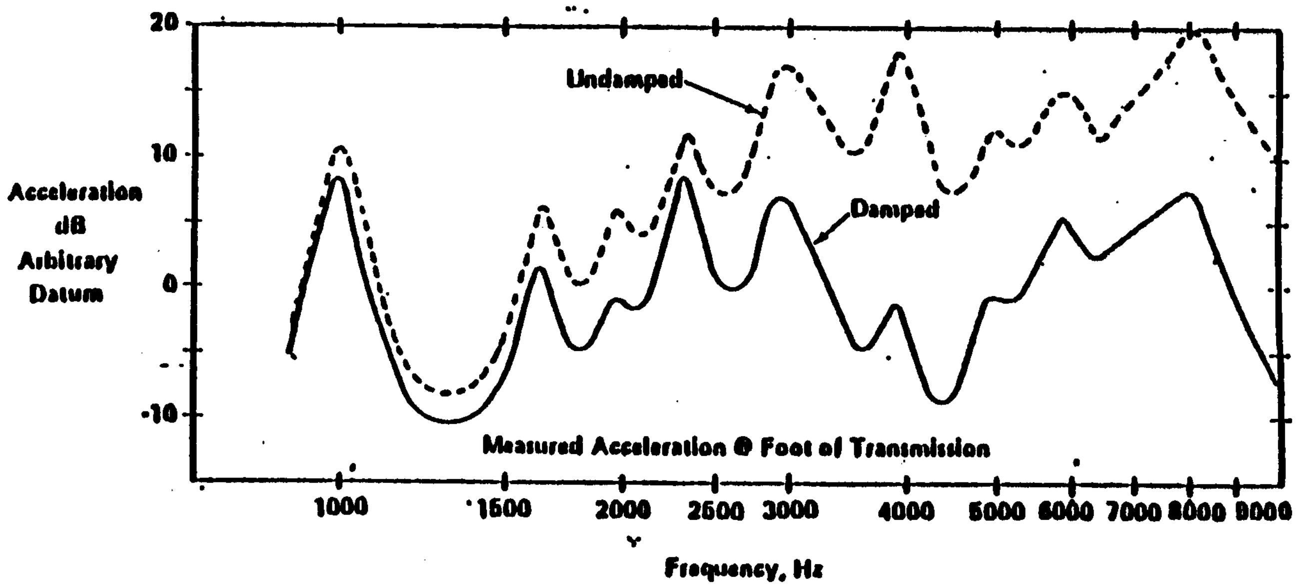
TRANSMISSION HOUSING DAMPING RESULTS IN SIGNIFICANT NOISE REDUCTION



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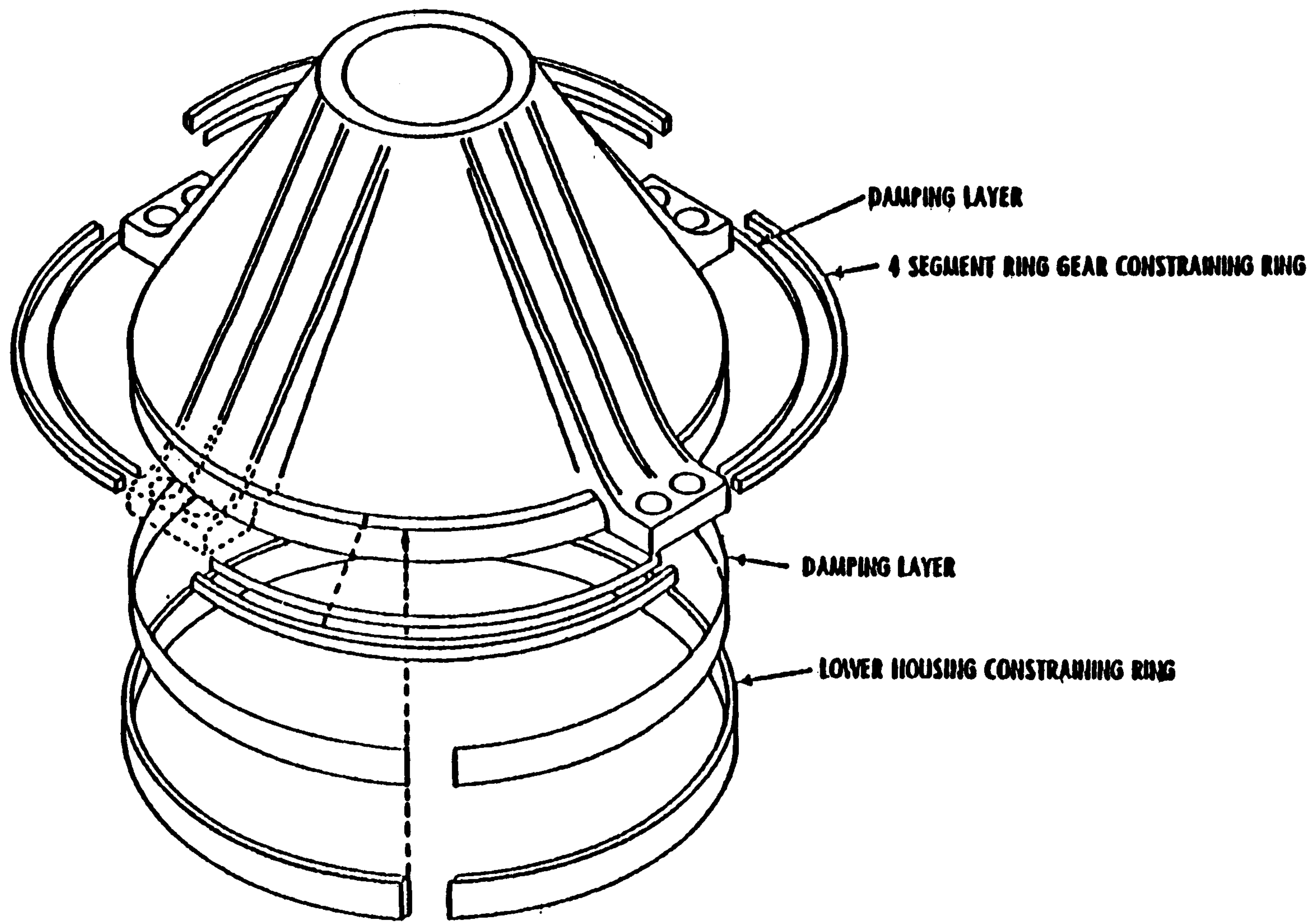
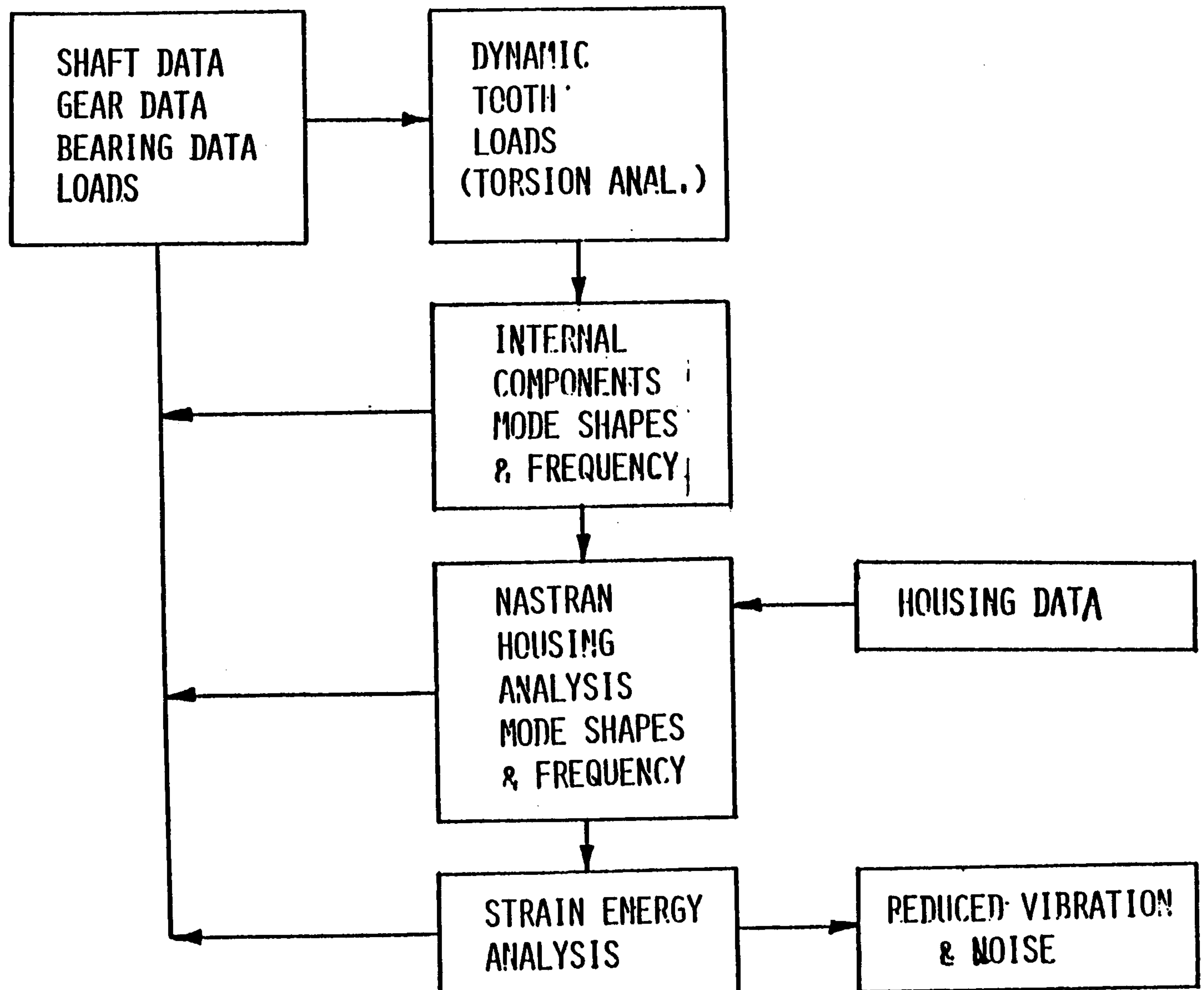
TECHNOLOGY TO RELIABLY ATTACH DAMPING MATERIAL MUST BE DEVELOPED



POWER TRAIN NOISE/VIBRATION ANALYSIS



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RECOMMENDED TRANSMISSION NOISE REDUCTION PROGRAM

1. USE A MODERN HELICOPTER TRANSMISSION TO ESTABLISH BASELINE.

2. EVALUATE EFFECTS OF MODIFICATIONS ON TRANSMISSION NOISE LEVELS.

   . DESIGN MODIFICATIONS BASED ON
     - CONCEPTS SHOWN TO HAVE POTENTIAL FOR NOISE REDUCTION
     - EXISTING DYNAMIC ANALYSIS PROGRAM
     - STUDY TO COMPARE VARIOUS PRODUCTION TRANSMISSION NOISE LEVELS, HCR GEARS, DAMPING CONCEPTS, ETC.

   . FABRICATE NEW COMPONENTS.

   . TEST ON REGENERATIVE TEST STAND INCLUDING ACOUSTIC MEASUREMENTS.

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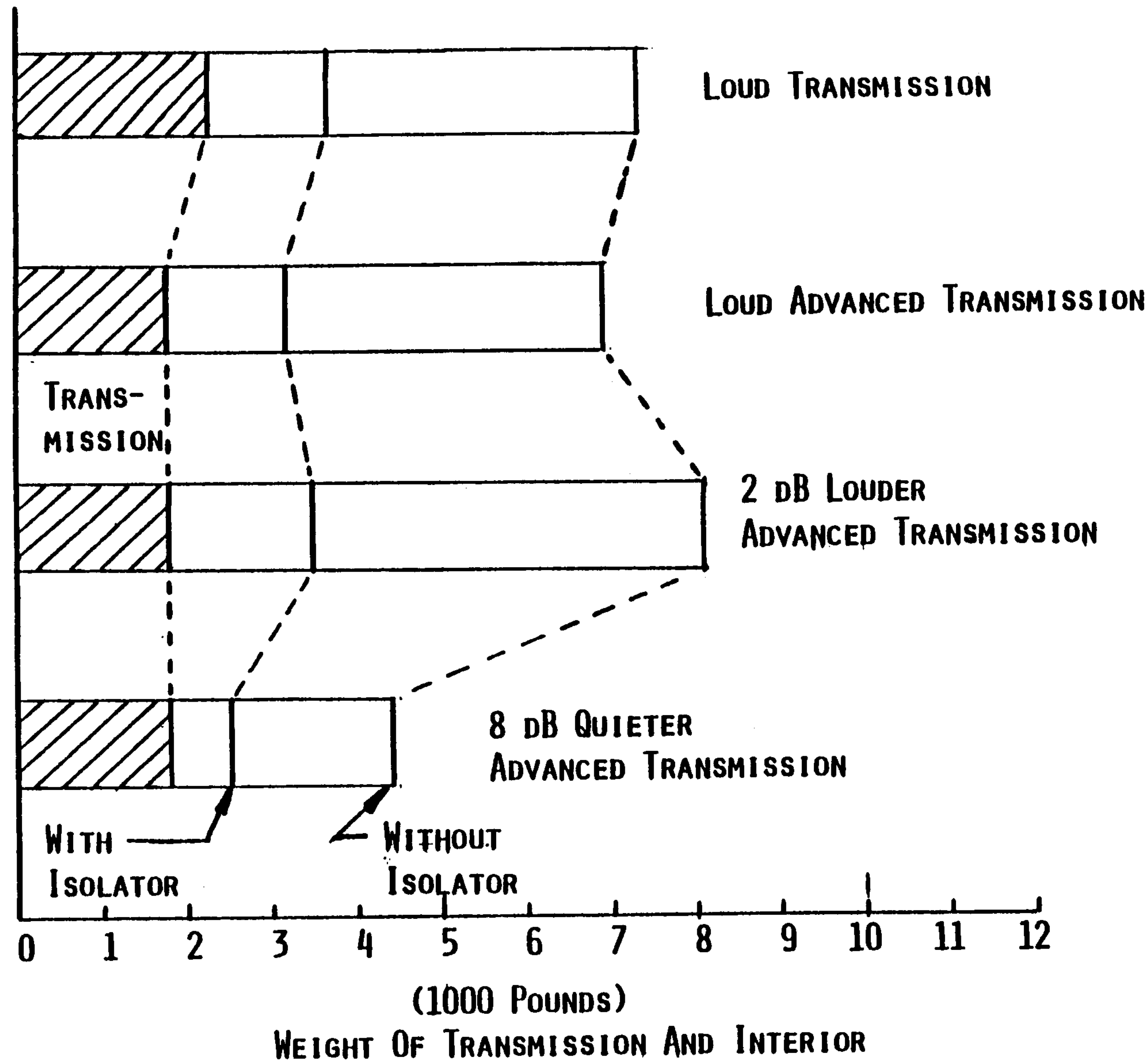
LOWERING GEARBOX NOISE HAS A SIGNIFICANT EFFECT ON HELICOPTER WEIGHT

4000 HP TRANSMISSION 75dB SIL



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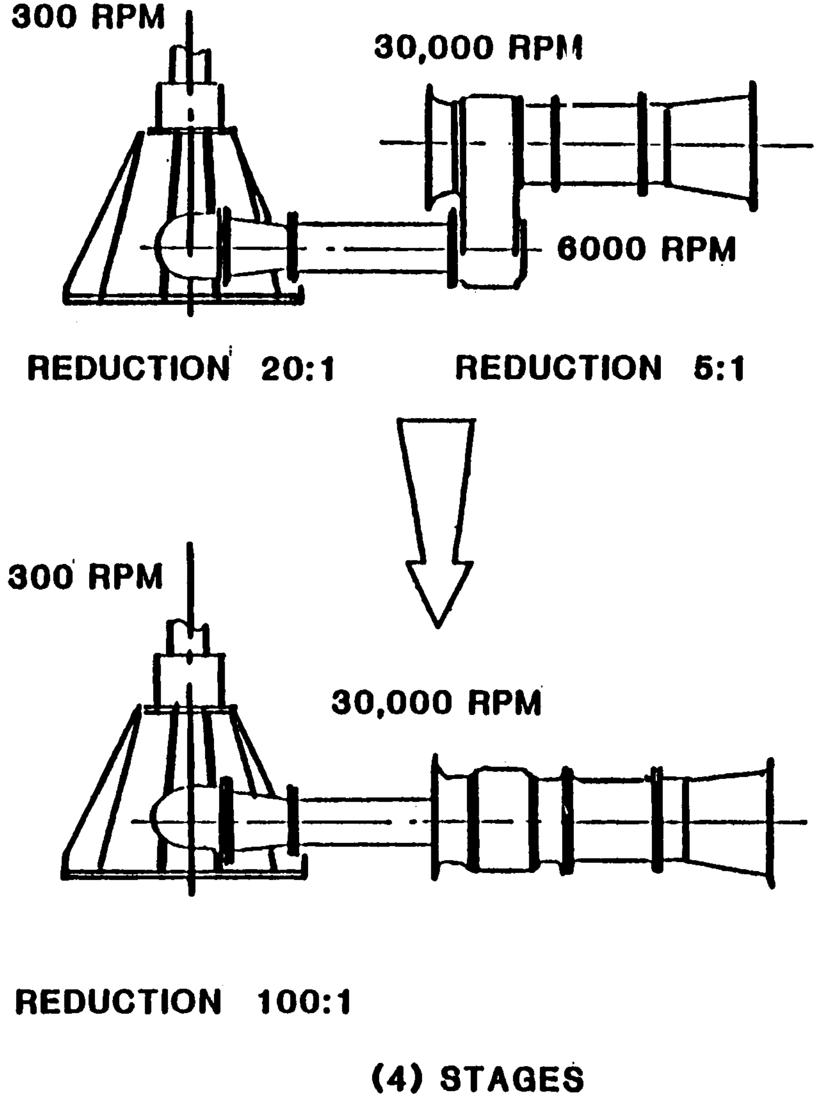
DIRECT ENGINE INPUT SIMPLIFIES SYSTEM INTEGRATION



- Simplified System Oil Cooling
- Fewer Reduction Stages
- Fewer Parts
- High Efficiency

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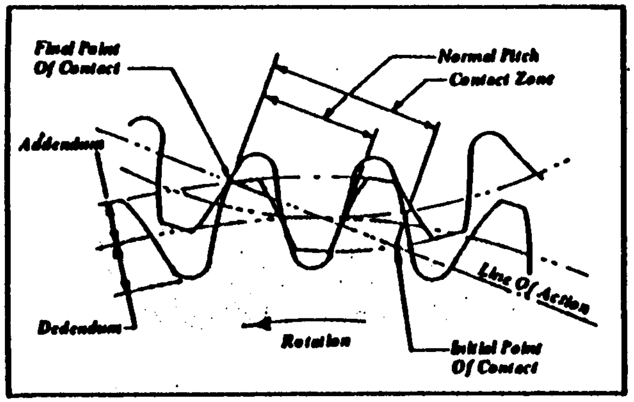
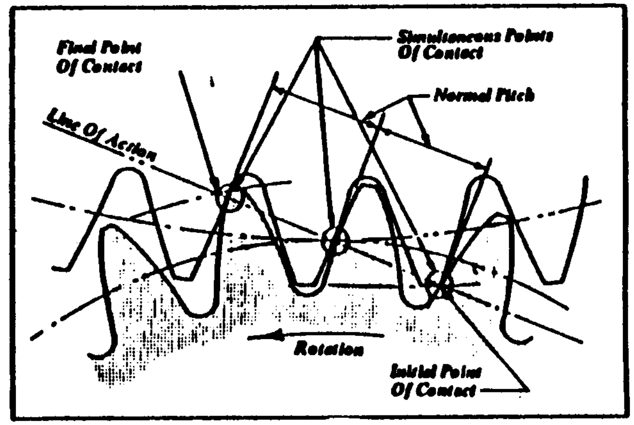
HIGH CONTACT RATIO GEARING REDUCES NOISE, INCREASES LOAD CAPACITY

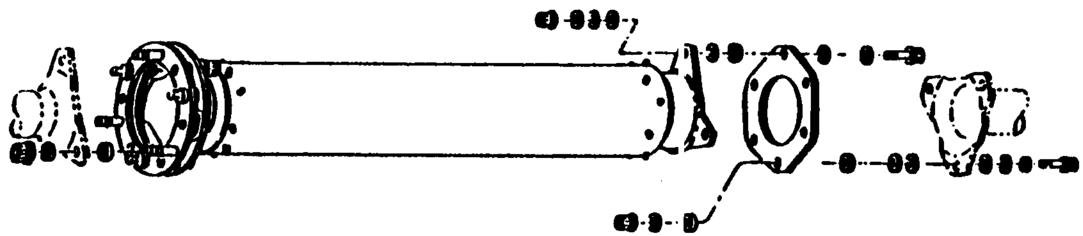
CONVENTIONAL GEARING

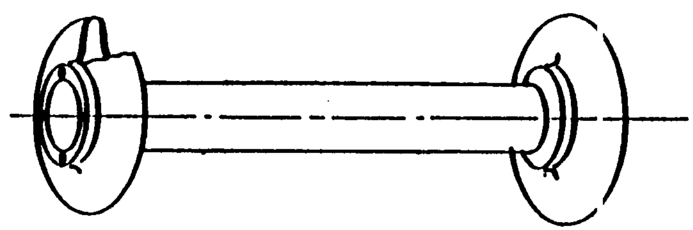




HIGH CONTACT RATIO GEARING

MODERN TECHNOLOGY PERMITS MORE RELIABLE SHAFT COUPLINGS





LIGHTWEIGHT
NO LOOSE PARTS (BALANCE)
NO FRETTING CONNECTION

COMPOSITE ENGINE DRIVE SHAFT WITH INTEGRAL COUPLINGS

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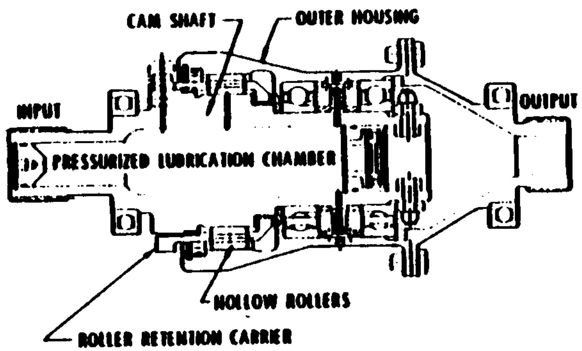
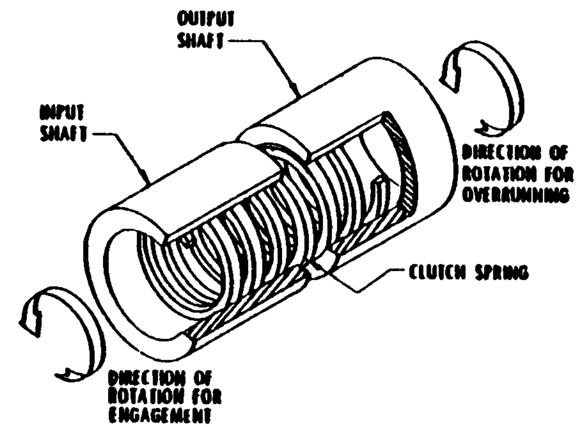
SIMPLE CLUTCH AT HIGH SPEED INPUT SAVES WEIGHT AND IMPROVES RELIABILITY



CONVENTIONAL ROLLER CLUTCH



ADVANCED SPRING CLUTCH

- HIGH RELIABILITY
- LOW PARTS COUNT
- SIMPLICITY
- LIGHTWEIGHT

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NASA PROPULSION RESEARCH

By Carl Matthys (Bell Helicopter Textron)

Three potential areas for NASA Propulsion Research are discussed. The first area is a review of helicopter direct operating costs points out the high percentage of fuel costs. Technology like composites, avionics, fly by light controls and rotor aerodynamics do not hold as much promise as engine and transmission technologies for reducing fuel consumption.

Approximately 90% of the helicopters in operation today weigh less than 6,000 lbs. and their small engines have the highest specific fuel consumption of all engines on the market today reflecting a need for small engine research.

The operators desire for safe twin engine operation is being reflected in FAA proposed rule making for the condition of one engine inoperative. Research here will ultimately change present engine controls and the present concept of engine ratings.

ADDRESS KEY AREAS

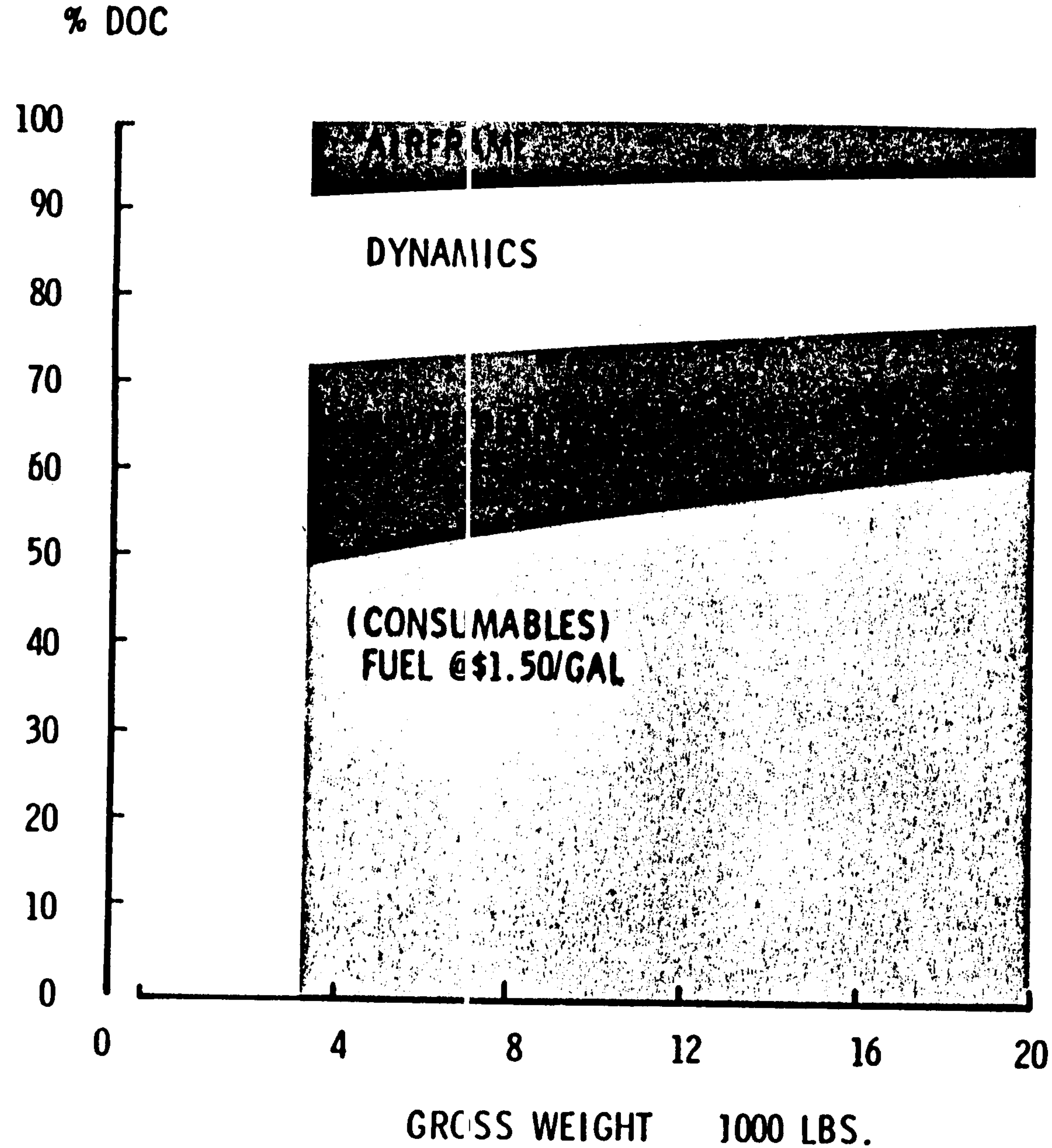
1 HELICOPTER D.O.C.

2 CATEGORY A OPERATIONS

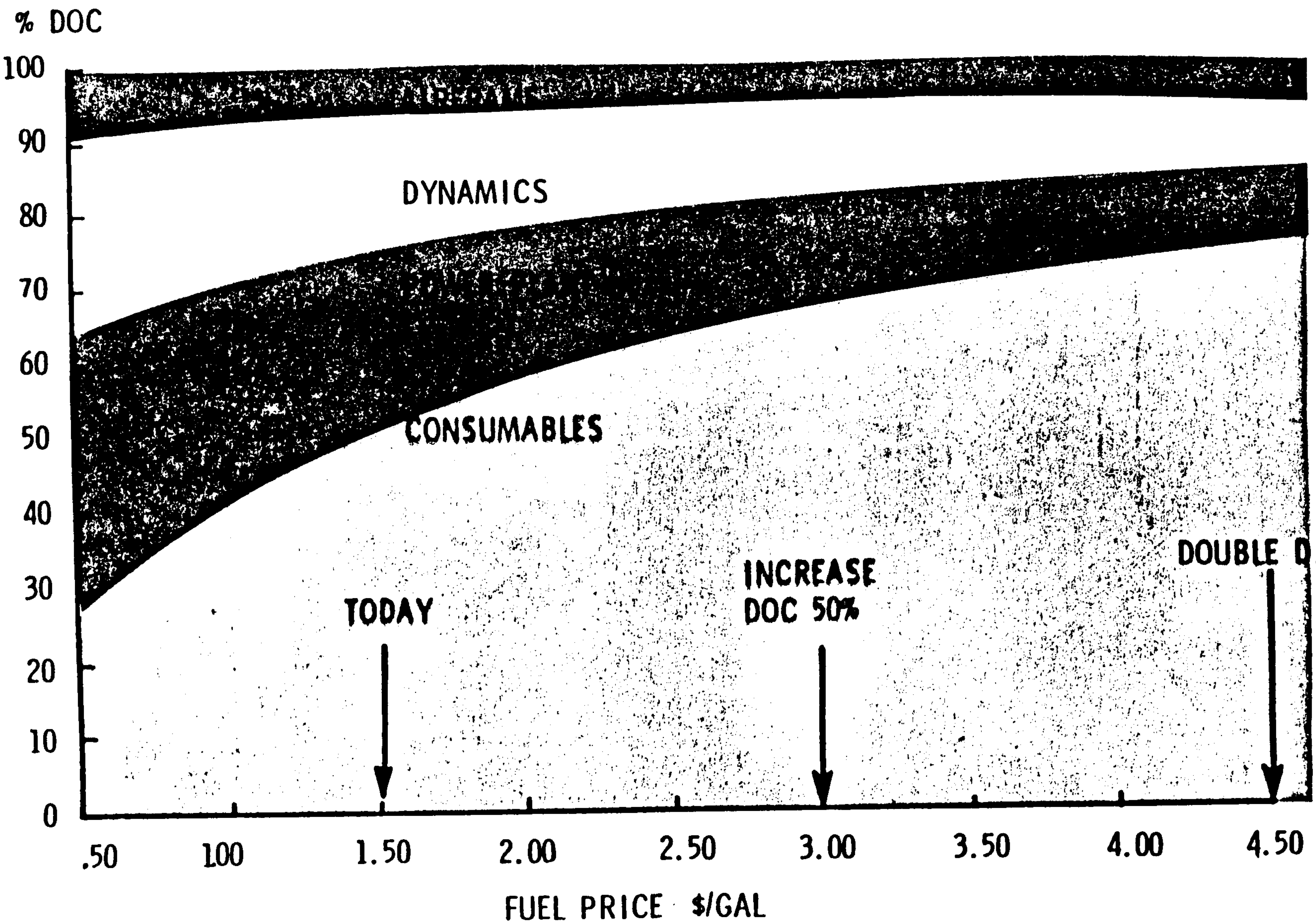
3 SMALL ENGINES

4 PRIORITIZE FUNDS

REVIEW HELICOPTER D.O.C. FOR COST DRIVERS



INCREASE FUEL COST FOR TYPICAL HELICOPTER



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ADVANCED TECHNOLOGY EFFECT ON THE AIRFRAME

	WEIGHT REDUCTION %	DRAG REDUCTION %	L/D IMPROVEMENT %	AIRCRAFT G. W. REDUCTION %
FUSELAGE	25	18	4	12½
ROTOR	5		10	4
[redacted]				
CONTROLS & HYDRAULICS	15			3
ELECTRICAL & AVIONICS	25			2

ADVANCED TECHNOLOGY REDUCES WEIGHT → 26%

LOWER THE COST OF HELICOPTERS

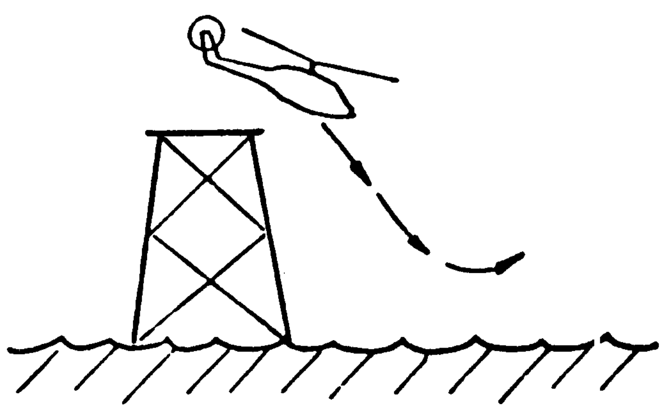
ENGINE TECHNOLOGY	REDUCES HELICOPTER GROSS WEIGHT BY
A VARIABLE GEOMETRY	12%
B VARIABLE GEOMETRY + RECUPERATOR	20%

ENGINE POTENTIAL EQUALS
SUM OF ALL OTHER TECHNOLOGY

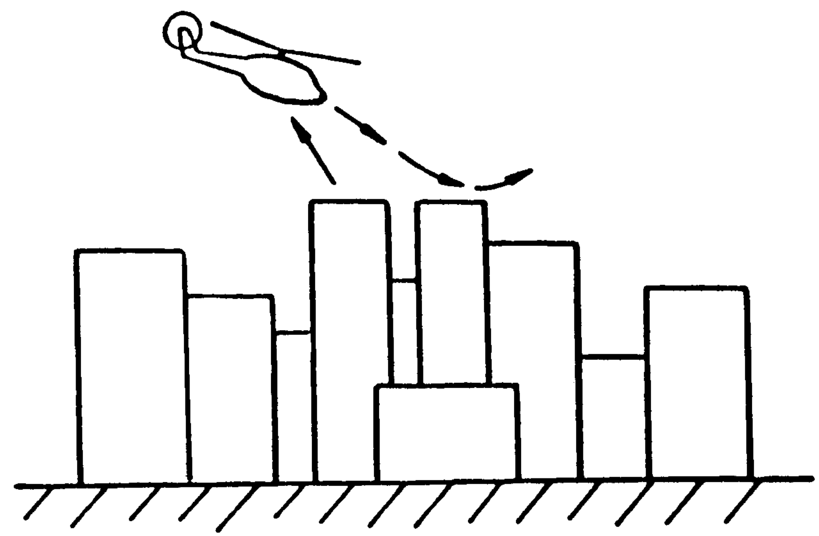
CATEGORY A REGULATION

MAKE CONTROLLED LANDING OR CONTINUE FLIGHT AFTER ONE ENGINE FAILURE

MAY BECOME MANDATORY FOR 9+ PASSENGER AIRCRAFT

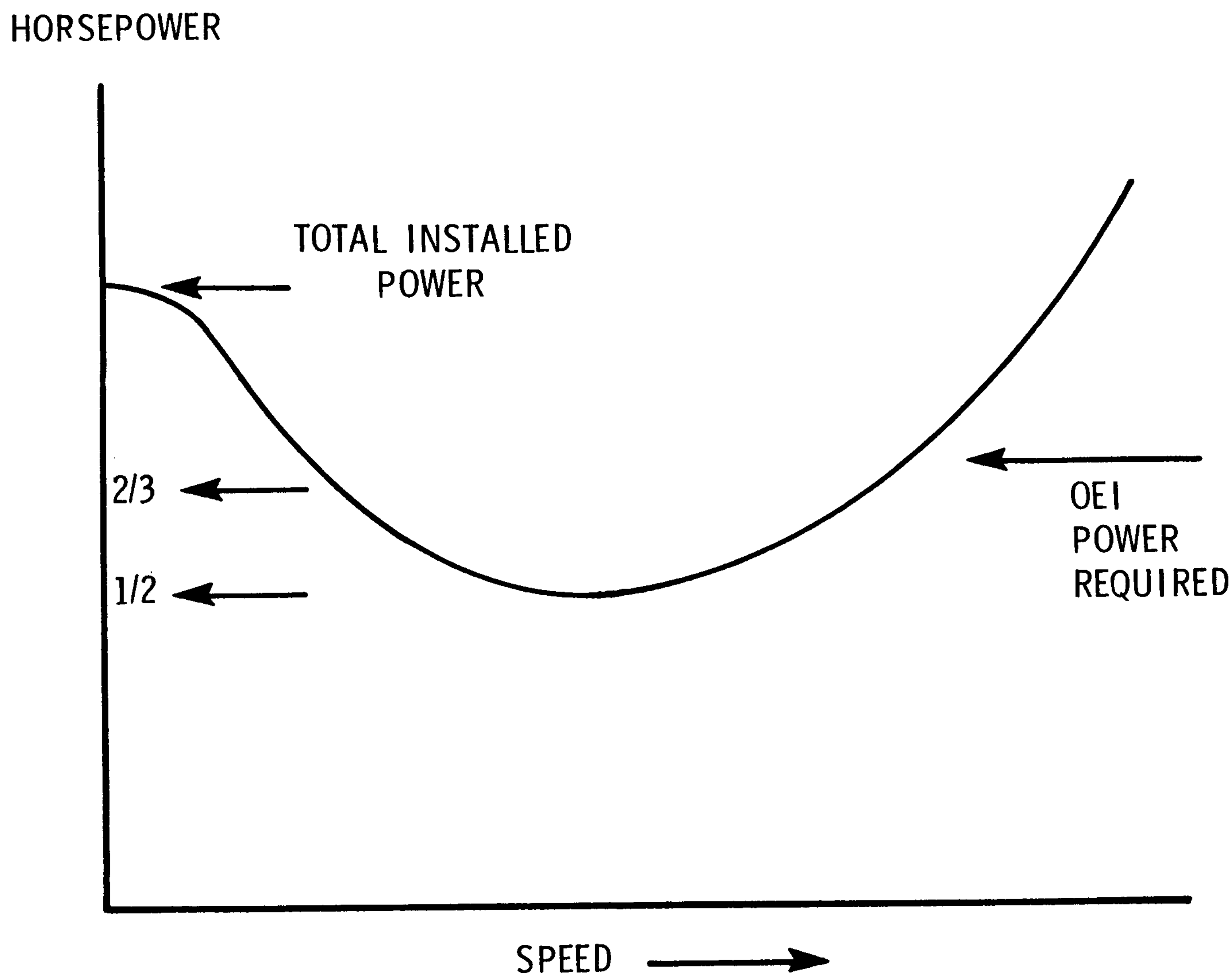


OIL RIG



URBAN HELIPORT

DESIGN FOR MORE POWER



FOR TWIN ENGINE OPERATION

FUEL CONTROL

CONTINGENCY RATINGS

TRADE MAXIMUM CONTINUOUS POWER
OR TAKEOFF POWER FOR ONE ENGINE
INOPERATIVE POWER

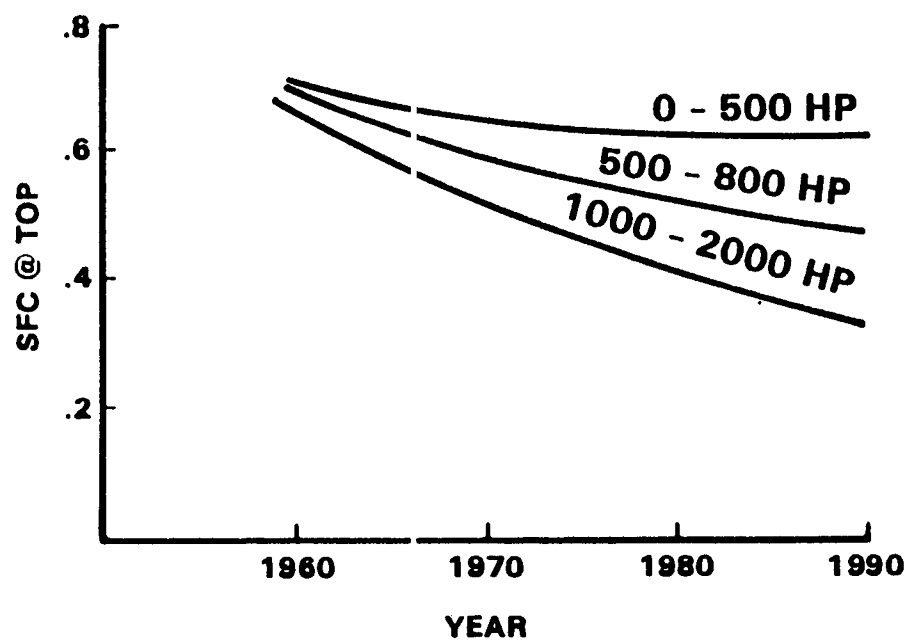
IF MORE THAN TWO ENGINES ARE USED

- FUEL CONTROL
- ENGINE SHUTDOWN AND RESTART
- ENGINE RATING

  NO OEI

  HIGHER MCP

HISTORICAL TRENDS OF TURBINE FUEL CONSUMPTION



SMALL ENGINE MARKET

TOTAL BHT LIGHT TURBINES

OH58
JET RANGER
LONG RANGER

6000+

PRESENT RATE 600 ANNUALLY

TOTAL BHT PISTON 5000+

THERE IS A MARKET FOR SMALL TURBINE

SMALL ENGINE TECGNOLOGY

- CF COMPRESSOR & POWER TURBINE
- FUEL CONTROL
- CLUTCH

PRIORITIZE TECHNOLOGY

1. FUEL ECONOMY
2. ONE ENGINE INOPERATIVE
3. SMALL ENGINES

PARAMETRIC STUDY ON THE INFLUENCE OF THE ENGINE UPON THE OPERATING COST OF A CIVIL HELICOPTER

BY GILBERT BEZIAC (AEROSPATIALE)

This study states the influence of engine characteristics (weight, fuel consumption, power, price, complexity, possible evolution) and of the fuel price upon the DOC and the cost per kg payload/km.

After having defined the parametric relationship between the various factors, several engine alternatives are compared for a helicopter like the Dauphin. These comparisons are made for two types of missions: off-shore over 900 km, corporate over 300 km.

A low specific fuel consumption, noticeable on the kg/km cost especially, is of particular interest for long missions.

An improved engine efficiency leads to an increased engine power and is consequently not profitable, which confirms the disadvantage of having excess engine power on a civil aircraft. This trend is reversed if it goes along with an increased gross weight of the aircraft and leads to a substantially improved aircraft efficiency.

Even with a 100% fuel price increase, only slight modifications appear in these comparisons. On the contrary, reducing the maintenance cost through longer MTBR or through the adoption of a modular type of maintenance noticeably lowers the operating cost of a helicopter.

INFLUENCE OF ENGINES ON CIVIL HELICOPTER OPERATING COST

– THEORETICAL APPROACH

- . ENGINE SELECTION CRITERIA
- . OPERATING COST COMPUTATION

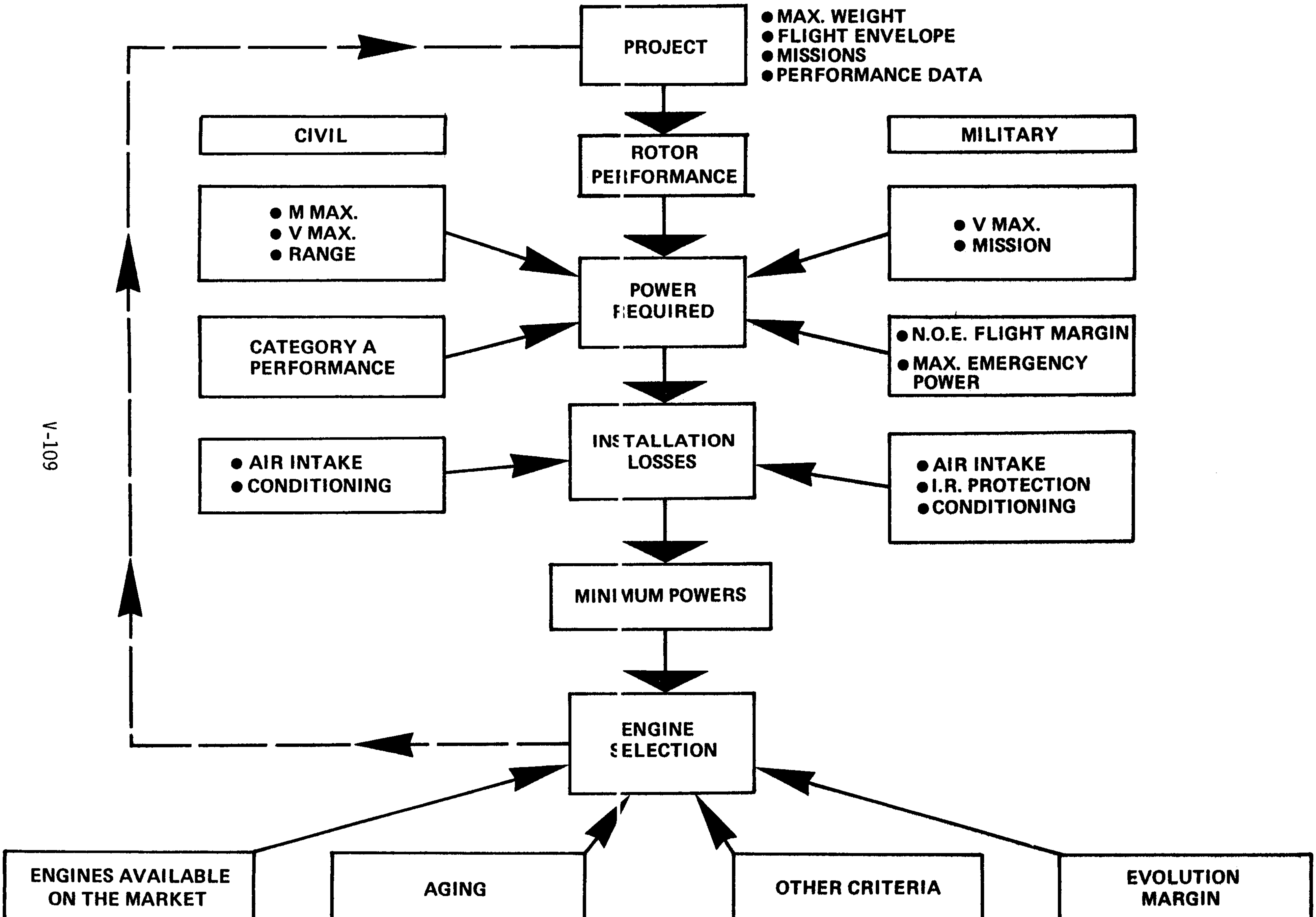
– APPLICATION ON A SA.365 N TYPE HELICOPTER

- . MISSION DEFINITION
- . INFLUENCE OF ENGINE PARAMETERS ON OPERATING COST
- . POSSIBLE EVOLUTIONS OF AN ENGINE
  - → . IMPACT ON COST
- . INFLUENCE OF ENGINE MAINTENANCE

– CONCLUSIONS

- . RESEARCH OBJECTIVES

ENGINE: SELECTION



NEW ENGINE SELECTION CRITERIA

ENHANCED HELICOPTER

OR

NEW PROJECT

- POWER LEVELS AT VARIOUS RATINGS

PRIORITY LEVELS VARIABLE WITH PROGRAM

- SPECIFIC FUEL CONSUMPTION
- WEIGHT
- PRICE
- RELIABILITY
- D.O.C.
- MAINTAINABILITY
- INSTALLATION PROBLEMS

- PROGRAM COMPATIBILITY
  LEADTIMES - PRODUCTION RATES

OPERATING COST PER FLYING HOUR

$$\boxed{DOC = \underbrace{A + B \cdot Pm}_{\text{YEARLY CHARGES AND HELICOPTER MAINTENANCE}} + \underbrace{\frac{C \cdot Pm}{(TBC)}}_{\text{ENGINE MAINTENANCE}} + \underbrace{W \cdot Pc \cdot C_S}_{\text{FUEL}}}$$

Pm : ENGINE PRICE

Pc : FUEL PRICE

A : FIXED COSTS WITHOUT ENGINE

B : ENGINE DEPRECIATION AND INSURANCE COEFFICIENT

PAYLOAD

$$\boxed{Cp = M - m - m_1 - W \cdot C_S \cdot t}$$

M : HELICOPTER TAKE-OFF WEIGHT

m : EMPTY WEIGHT + CREW −ENGINES

m_1 : ENGINE WEIGHT

$W \cdot C_S \cdot t$: FUEL WEIGHT

t : MISSION TIME

$$\boxed{\text{COST OF PAYLOAD lb/n.m.} = \frac{D.O.C.}{Cp \cdot V}}$$

V : HELICOPTER AVERAGE SPEED

PRACTICAL CALCULATION METHOD

$$\boxed{\frac{DOC}{DOC_o} = 1 + \frac{\Delta(DOC)}{DOC_o} = A' + B' \frac{P_m}{P_{mo}} + C' \frac{P_m}{P_{mo}} \frac{(TBO)_o}{TBO} + W' \frac{P_c}{P_{co}} \frac{C_s}{C_{so}}}$$

$$A' = \frac{A}{DOC_o} \qquad B' = \frac{B . P_{mo}}{DOC_o} \qquad C' = \frac{C . P_{mo}}{DOC.(TBO)_o} \qquad W' = \frac{W . C_{so} . P_{co}}{(DOC)_o}$$

$$\boxed{\frac{C_p}{C_{po}} = 1 + \frac{\Delta(C_p)}{C_{po}} = M' - \frac{m_1}{m_{1o}} \frac{m_{1o}}{C_{po}} - \frac{W . C_{so}}{C_{po}} \frac{C_s}{C_{so}} t}$$

$$M' = \frac{M - m}{C_{po}}$$

HYPOTHESES | $W_{CRUISE} = cst$; $V_{CRUISE} = cst$

INFLUENCE FACTORS

M=8380 lb

	OFF-SHORE MISSION DISTANCE COVERED 2 x 2[illegible]0 N.m.		CORPORATE MISSION DISTANCE COVERED : 160 N.m. APPROX.	
+ 10 % ON ENGINE PRICE	D.O.C.	+ 1,8 %	D.O.C.	+ 1,6 %
	Cp	0 %	Cp	0 %
	LB/Nm COST	+ 1.8 %	LB/Nm COST	+ 1.6 %
– 10 % ON SPECIFIC CONSUMPTION	D.O.C.	– 2.2 %	D.O.C.	– 1.8 %
	Cp	+15.2 %	Cp	+ 3.8 %
	LB/Nm COST	–17.4 %	LB/Nm COST	– 5.6 %
+ 10 % ON ENGINE WEIGHT	D.O.C.	0 %	D.O.C.	0 %
	Cp	– 4,5 %	Cp	– 2,6 %
	LB/Nm COST	+ 4,5 %	LB/Nm COST	+ 2,6 %
TBO x 2	D.O.C.	– 5,5 %	D.O.C.	– 4,4 %
TBO x 1.5	D.O.C.	– 3,7 %	D.O.C.	– 2,9 %

APPLICATION TO AN SA 365 N TYPE HELICOPTER

MISSIONS

	OFF-SHORE MISSION	CORPORATE MISSION
RANGE	2 x 200 N.m.	160 N.m.
FUEL QUANTITY (BASIC ENGINE)	1984 lb	882 lb
YEARLY OPERATING TIME	1500 h/YEAR	1000 h/YEAR

APPLICATION TO AN SA 365 N TYPE HELICOPTER

WEIGHTS

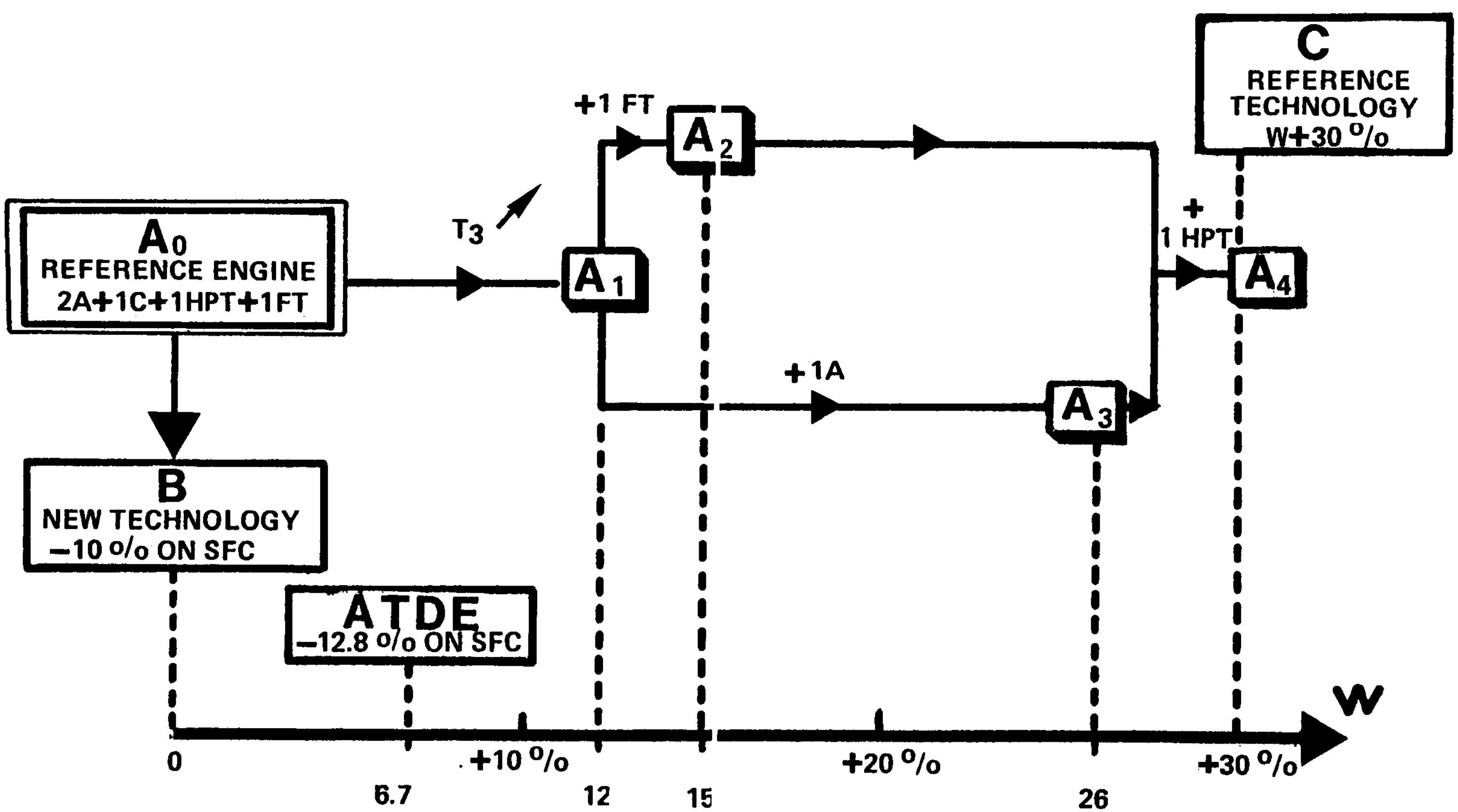
	OFF-SHORE MISSION	CORPORATE MISSION
WEIGHT WITHOUT ENGINE, WITH CREW	4488 lb	4594 lb
FUEL	1984 lb	882 lb
PAYLOAD	1310 lb	2306 lb
REFERENCE ENGINE	595 lb	595 lb
REFERENCE ALL-UP WEIGHT	8380 lb	8380 lb

CALCULATION OF D.O.C. PER FLYING HOUR

FOR REFERENCE AIRCRAFT (SA 365 N)

MISSION	OFF-SHORE	CORPORATE	
YEARLY OPERATING TIME	1 500 HR/YEAR	1 000 HR/YEAR	HYPOTHESES
	F/HR	F/HR	. BASIC A/C COST 1.48 M$
MAINTENANCE :			. OPTIONAL EQUIPt 0.31 M$
HELICOPTER	415	415	
ENGINE	212	212	. ENGINES 24 o/o BASIC A/C COST
YEARLY COSTS :			
AMORTIZEMENT : HELICOPTER	326	489	. AMORTIZEMENT OVER 10-YEAR PERIOD
ENGINE	74	111	20 o/o RESIDUAL VALUE
HELICOPTER INSURANCE	203	305	. FUEL PRICE IN FRANCE
(Tx = 5 o/o) ENGINE	47	70	IN JUNE 80 1.1 $ US GALLON
CREW	200	380	
FUEL	426	426	TAX EXCLUDED
TOTAL	1903 F/HR I.E.: 453 $/HR	2 408 F/HR I.E.: 573 $/HR	

POSSIBLE ENGINE EVOLUTIONS



EVOLUTIONS OF REFERENCE ENGINE

ENGINE	CONFIGURATION	T3	ΔPRICE	REMARKS
A0	2A + 1C 1HPT + 1FT	1350°K (NOT COLLED)		
A1	2A + 1C 1HPT + 1FT	1425°K (COOLED)	+ 5 o/o	T3 INCREASED (H.P. TURBINE COOLING)
A2	2A + 1C 1HPT + 2FT	1425°K (COOLED)	+17 o/o	2 FREE TURBINE STAGES
A3	3A + 1C 1HPT + 1FT	1425°K (COOLED)	+ 9,7 o/o	PRESSURE RATIO INCREASED (3 AXIAL STAGES, n = 12–12.5)
A4	3A + 1C 2HPT + 2FT	1400°K (COOLED)	+39,7 o/o	PRESSURE RATIO 14′
B	3A + 1C 2HPT + 2FT	1400°K (COOLED)	+40 o/o	REFERENCE ENGINE POWER TECHNOLOGY ≡ A4
C	2A + 1C 1HPT + 1FT	~1350°K	+ 10 o/o	REFERENCE ENGINE TECHNOLOGY POWER ≡ A4
ATDE	2C 2HPT + 2FT		~+ 40 o/o	

HPT = HIGH PRESSURE TURBINE   A = AXIAL
FT = FREE TURBINE   C = CENTRIFUGAL

EVOLUTIONS OF REFERENCE ENGINE

ENGINE	Δ W (~~MAX.~~ ~~CONTING~~. ~~POWER~~)	ΔC_S AT 55 o/o FROM ANALYSIS POINT	ΔC_S (536 hp)	WEIGHT Δ
A0	PMU REF. (912 hp.)	REF. (0,609 lb/hp. h.)	REF. (0,596 lb/hp. h.)	REF. (300 lb)
A1	+12 o/o	− 3,5 o/o	0 o/o	0 o/o
A2	+14,5 o/o	− 5 o/o	−1,5 o/o	11 o/o
A3	+26 o/o	− 4 o/o	+4,5 o/o	5 o/o
A4	+30 o/o	−10 o/o	−1 AT−2 o/o (−1,5 o/o)	25 o/o
B	0 o/o	−10 o/o	−10 o/o	+10 o/o
C	+30 o/o	0 o/o	+11,5 o/o	+20 o/o
ATDE	+ 6,7 o/o		−12,8 o/o	− 9 o/o

ENGINE EVOLUTIONS

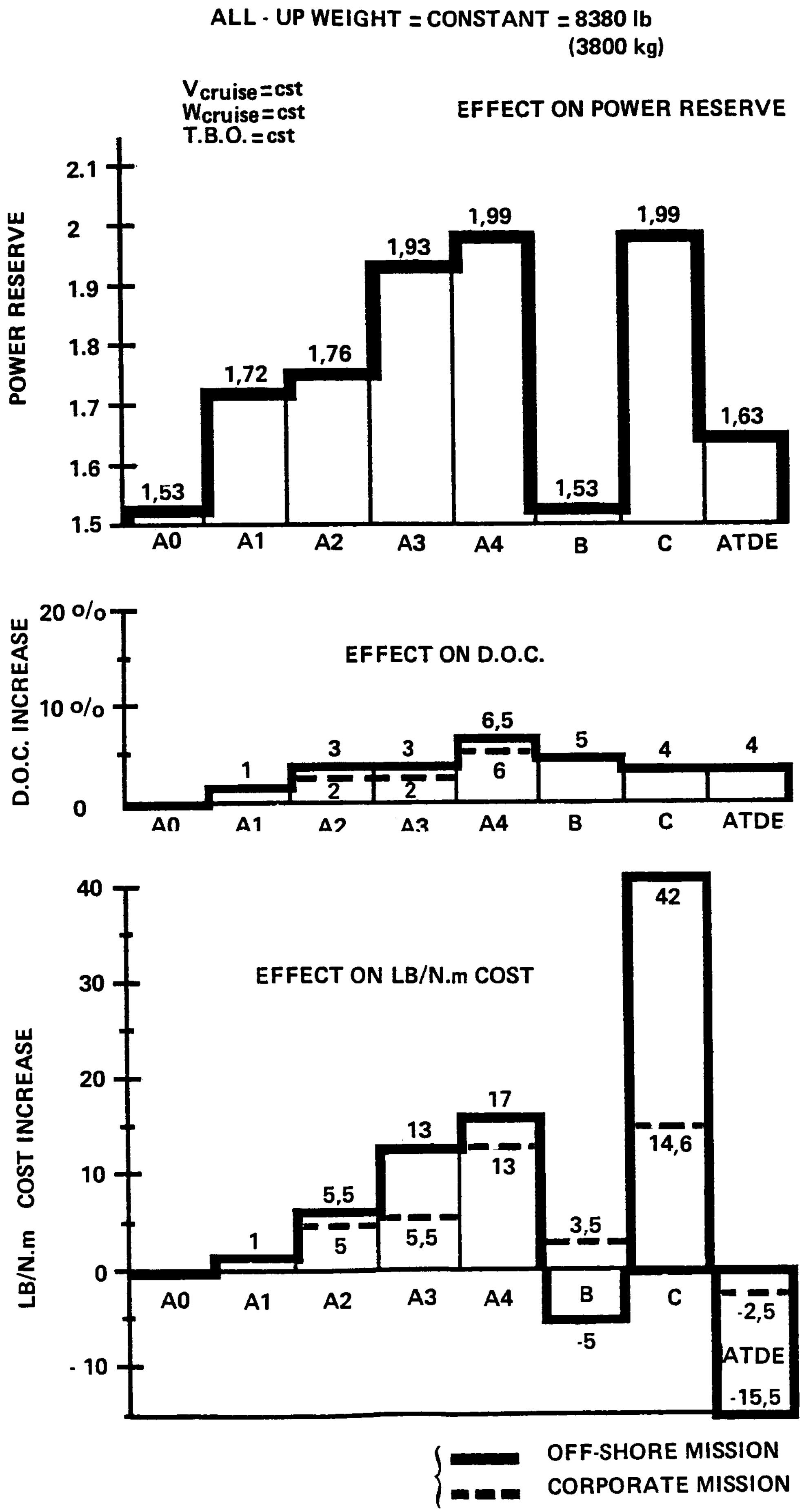
EFFECT ON OPERATING COST

3 HYPOTHESES

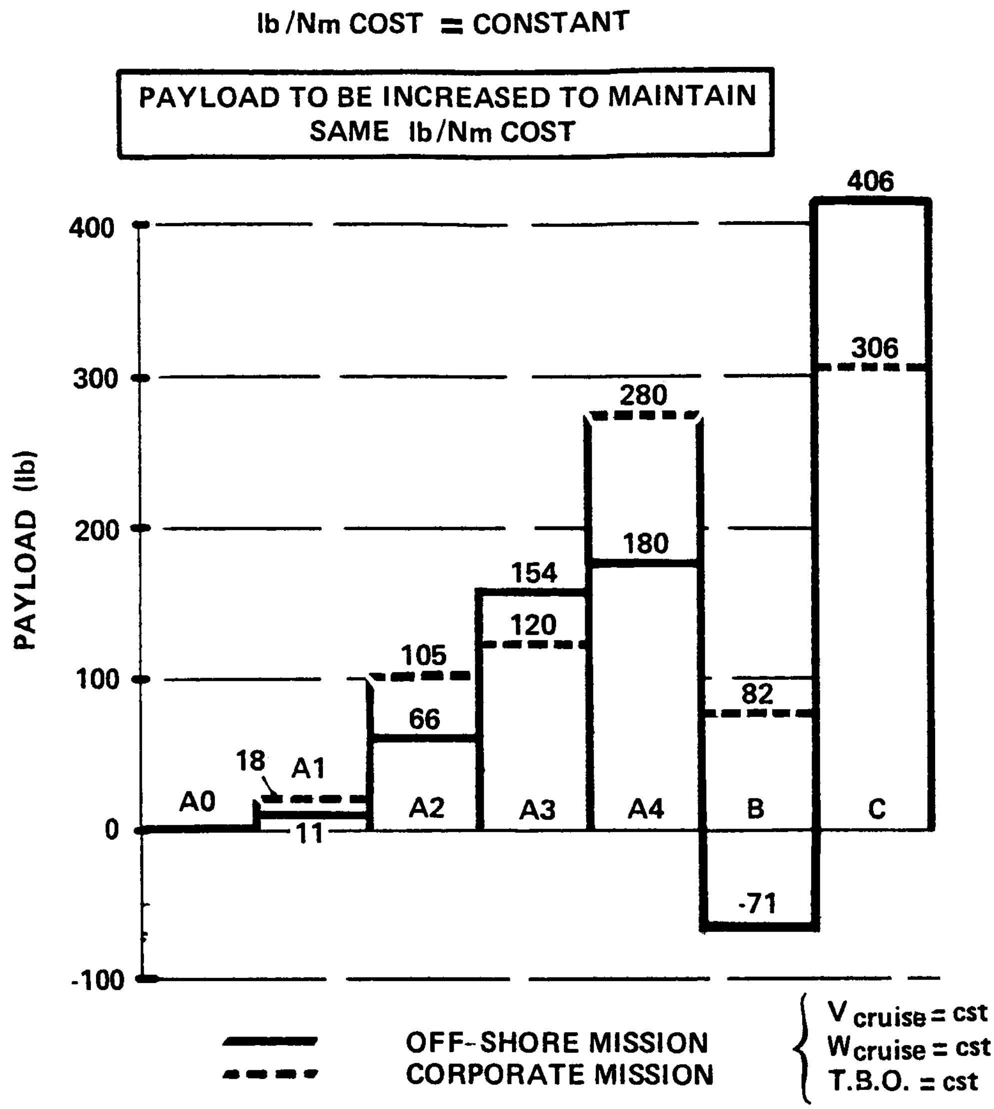
- ALL-UP WEIGHT = CONSTANT
- LB/N.m COST = CONSTANT
- POWER RESERVE = CONSTANT

$$* \text{ POWER RESERVE} = \frac{\text{POWER INSTALLED}}{\text{POWER REQUIRED}}$$ HOVER, O.G.E., I.S.A. CONDITIONS

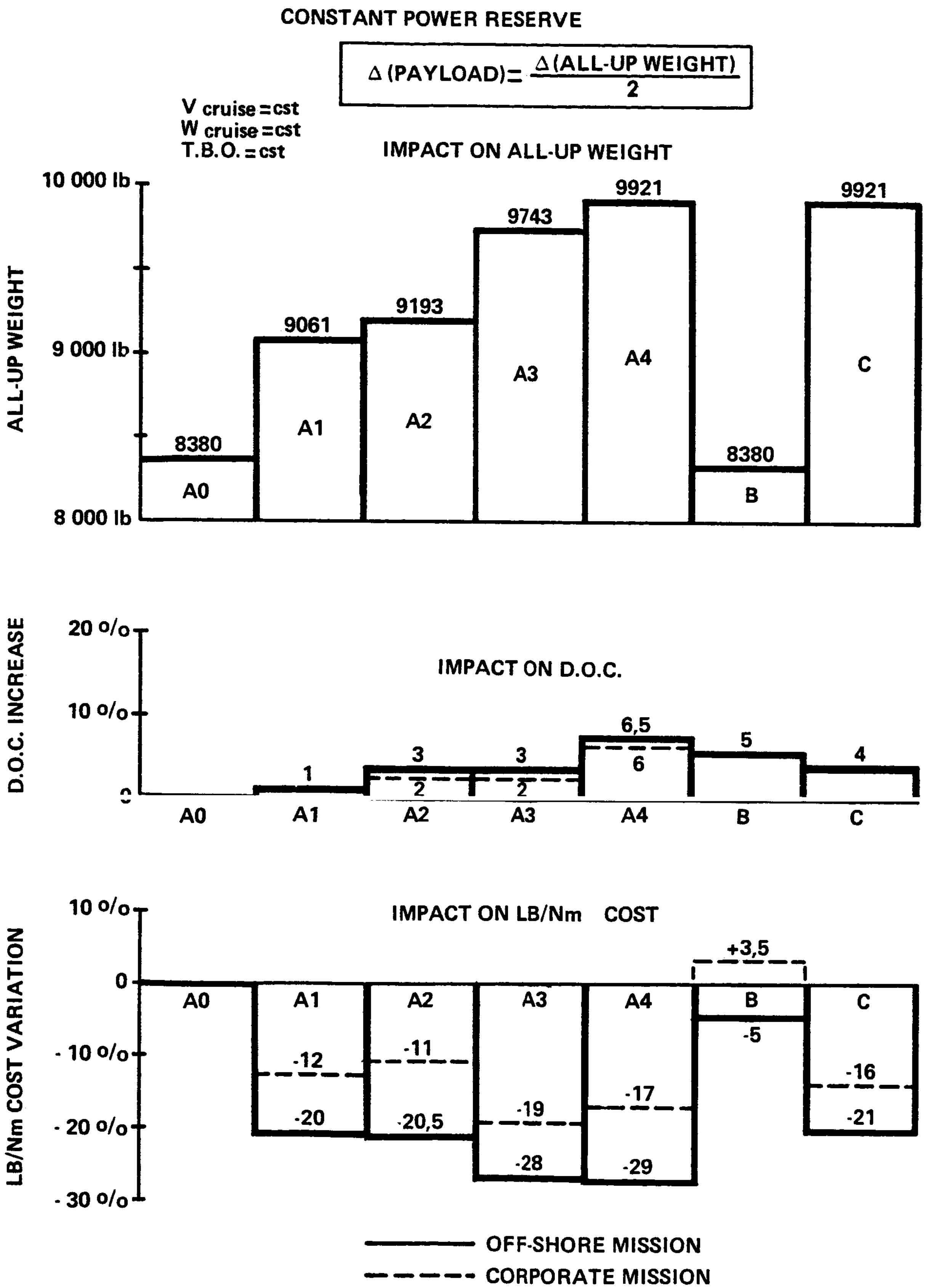
EVOLUTION OF REFERENCE ENGINE



EVOLUTION OF REFERENCE ENGINE



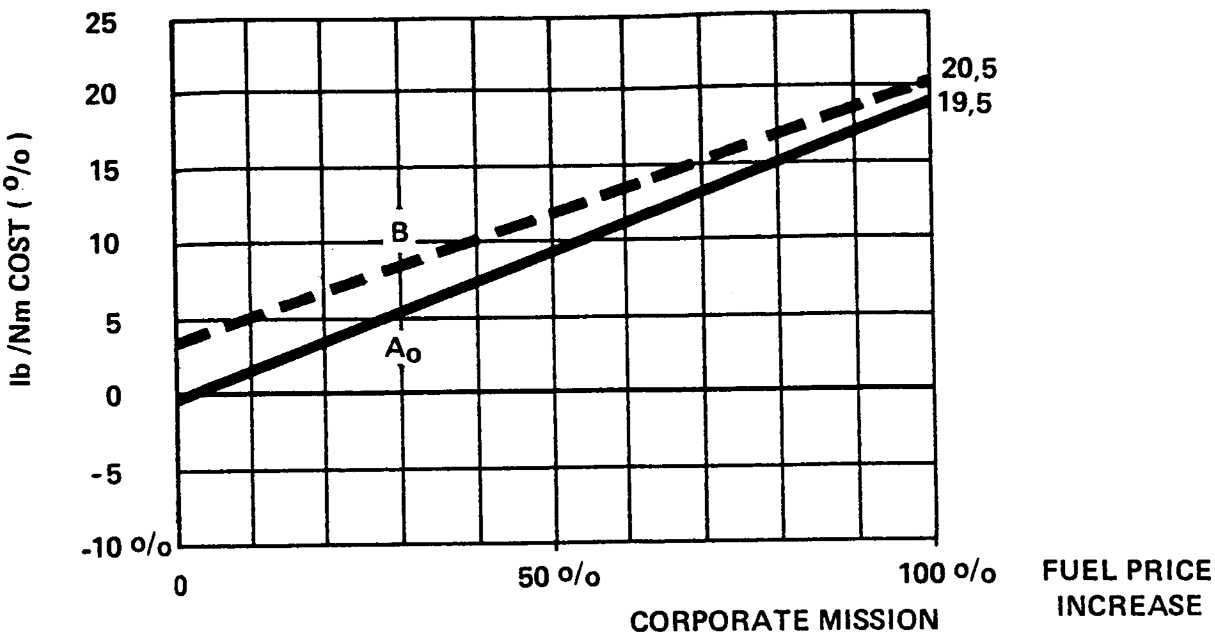
EVOLUTION OF REFERENCE ENGINE

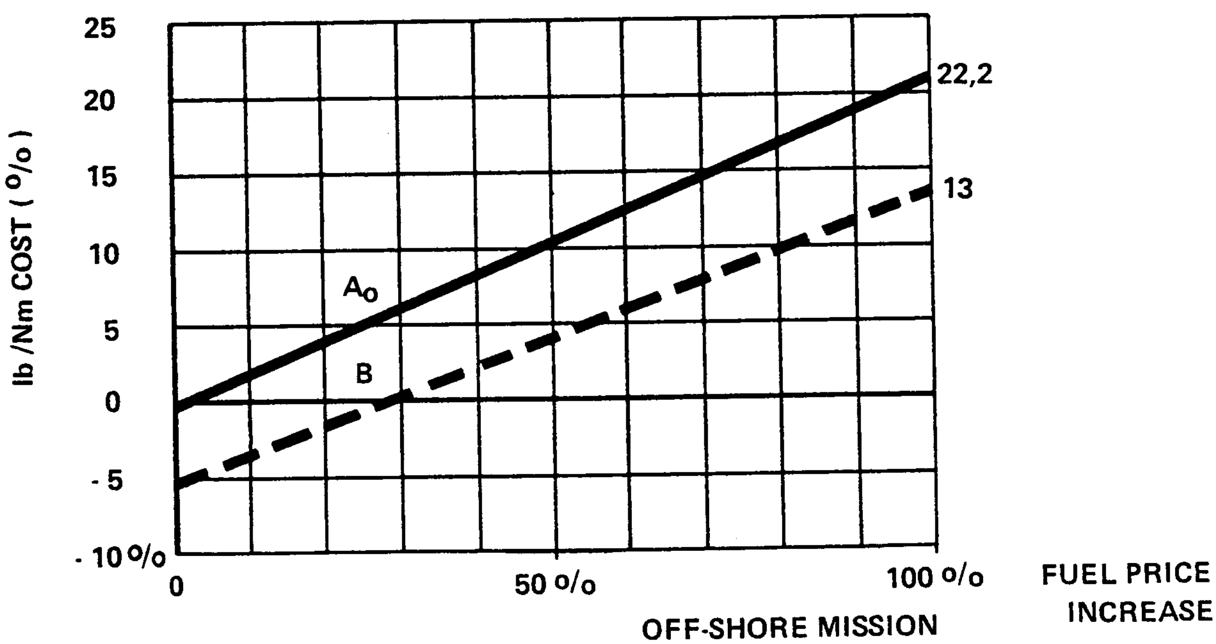


FUEL PRICE INCREASE

EFFECT ON OPERATING COST

SAME INSTALLED POWER
M = 8380 lb (3800 kg)

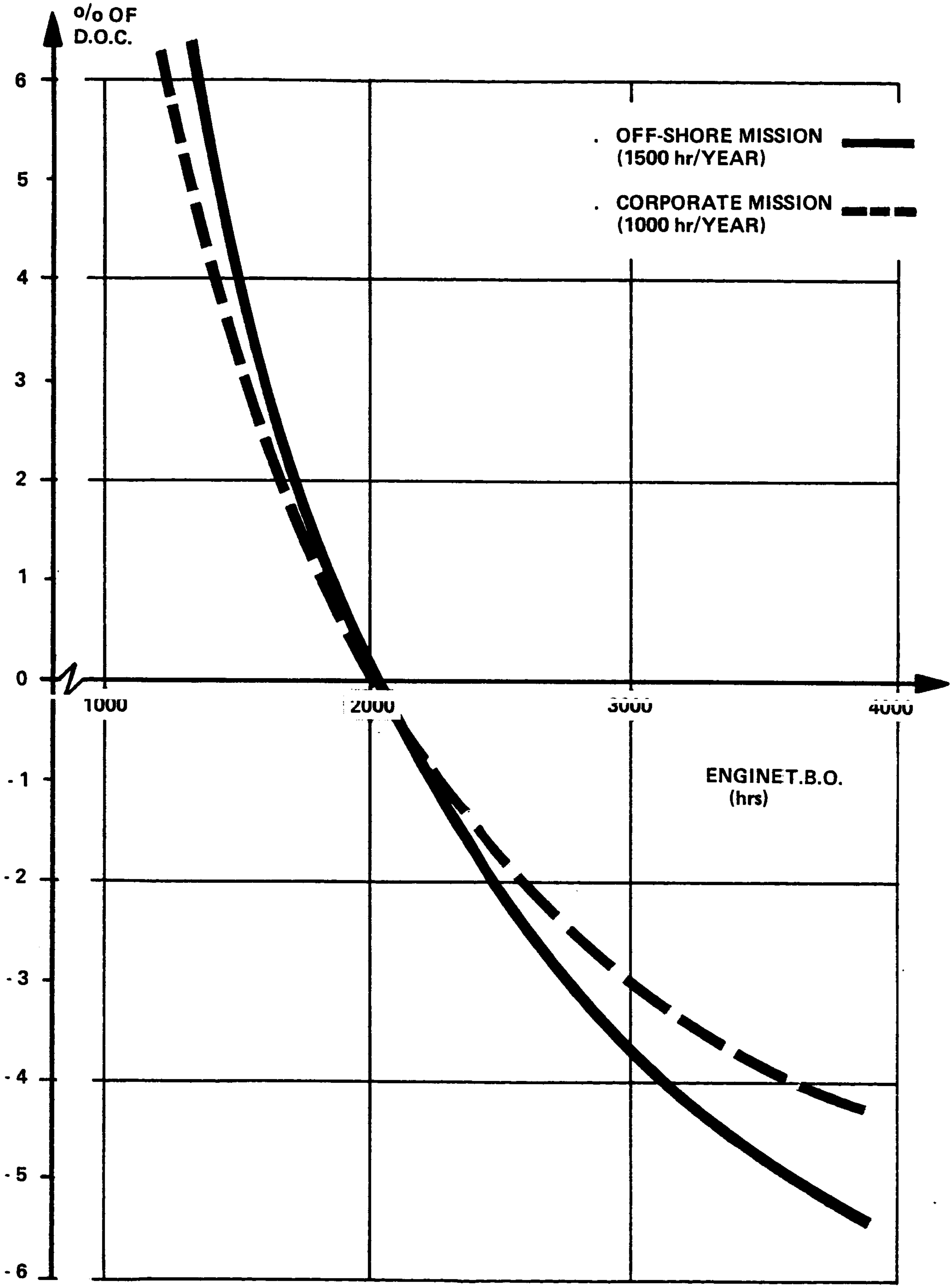




A0 REFERENCE ENGINE

B NEW TECHNOLOGY - SAME POWER (-10 o/o ON SFC)

IMPACT OF T. B. O. ON D.O.C.



CONCLUSIONS

- UNFAVURABLE EFFECT OF EXCESS POWER (AT SAME TECHNOLOGY) ON D.O.C. AND lb/Nm COST
- REQUIREMENT TO MATCH AIRCRAFT AND ENGINE EVOLUTIONS
  → INCREASE IN ALL-UP WEIGHT
- IMPORTANCE OF POWER LEVEL SELECTION FOR A NEW PROJECT
  → WEIGHT INCREASE PREDICTION
- EFFECT OF FUEL PRICE INCREASE : INTEREST OF A LOW SFC
- IMPORTANCE OF MAINTENANCE, SFC, AND SPECIFIC WEIGHT OF THE ENGINE

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RESEARCH AIMS FOR CIVIL HELICOPTER ENGINES

- DECREASE IN SPECIFIC CONSUMPTION
- IMPROVEMENT OF RELIABILITY
  - INCREASED TBO AND MTBR
  - ON CONDITION AND MODULAR MAINTENANCE
- DECREASE IN SPECIFIC WEIGHT

---

* PARAMETERS ARE ALL THE MORE SIGNIFICANT AS THE MISSION DISTANCE IS LONG

SYMBOLS

D.O.C.	DIRECT OPERATING COST
T.B.O.	TIME BETWEEN OVERHAUL
A	FIXED COSTS OF AIRCRAFT WITHOUT ENGINE
B	ENGINE DEPRECIATION AND INSURANCE COEFFICIENT
C	ENGINE MAINTENANCE COEFFICIENT
W	POWER REQUIRED TO THE MISSION
M	AIRCRAFT WEIGHT
m_1	ENGINES WEIGHT
m	$M - m_1$
Cp	PAYLOAD
Pc	FUEL PRICE
Pm	ENGINE PRICE
C_S	SPECIFIC FUEL CONSUMPTION
t	MISSION TIME
V	AIRCRAFT SPEED
T_3	COMBUSTION CHAMBER TEMPERATURE

HAA/NASA ADVANCED ROTORCRAFT WORKSHOP

PROPULSION SUB-SESSION

BY DAVID WOODLEY - BOEING VERTOL COMPANY

The impact of engine ratings on aircraft performance and size is discussed, including power relationships for different phases of flight and the effect of power available on category A take-off distance. Desirable engine characteristics are described relative to fuel consumption, operational characteristics and limitations, performance growth and engine deterioration.

In addition, current and future advances in drive system technology are discussed.

BOEING VERTOL
DAVID WOODLEY

ENGINE PERFORMANCE AND RATINGS

- MULTI-ENGINE HELICOPTERS USED FLEXIBLE THRUST LONG BEFORE FIXED-WING JETS.
- HELICOPTER PAYLOAD IS USUALLY LIMITED TO ACCOUNT FOR ENGINE FAILURES THAT RARELY HAPPEN.
  - ENGINE FAILURE AT CRITICAL TAKEOFF POINT
  - ENGINE FAILURE ENROUTE AT HIGH GROSS WEIGHT, FAR FROM SAFE LANDING
- ENGINE MUST BE RATED TO COMPENSATE FOR ONE-ENGINE-INOPERATIVE (OEI) REQUIREMENTS, TO REDUCE AIRCRAFT WEIGHT AND COST AND FUEL BURN.

- TAKEOFF OEI POWER	2½-MINUTE OEI/MAXIMUM CONTINGENCY
- ENROUTE OEI POWER	30-MINUTE OEI/INTERMEDIATE CONTINGENCY
- TAKEOFF POWER	5-MINUTE
- MAXIMUM CONTINUOUS POWER	MAY BE LIMITED TO OEI BY ENGINE MANUFACTURER
- MAXIMUM CRUISE POWER	POTENTIAL MANUFACTURER IMPOSED LIMITS

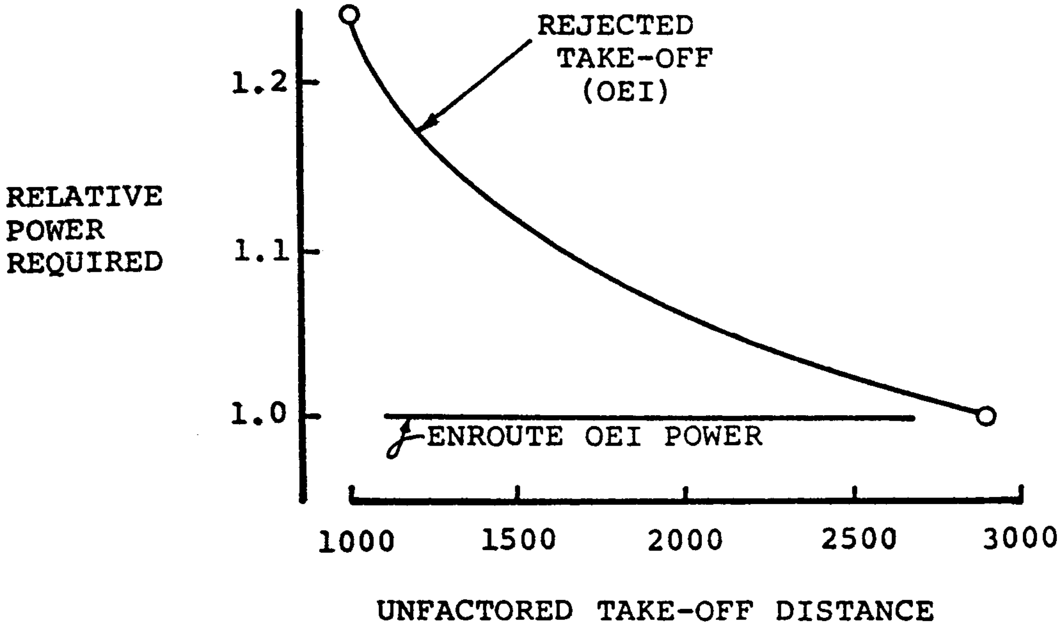
- THE ENGINE WILL BE DESIGNED BY ONE OF THESE RATINGS - MOST LIKELY ONE OF THE OEI RATINGS. FURTHER, THE OEI RATINGS WILL BE BASED UPON THE MOST DEMANDING OF THE FOLLOWING CONSIDERATIONS:

- CERTIFICATION EFFORT	- ANTICIPATED OPERATIONAL EXPOSURE
ENDURANCE TEST	ACTUAL OEI
INTEGRITY TEST	POWER CHECKS
LOW CYCLE FATIGUE TEST	TRAINING

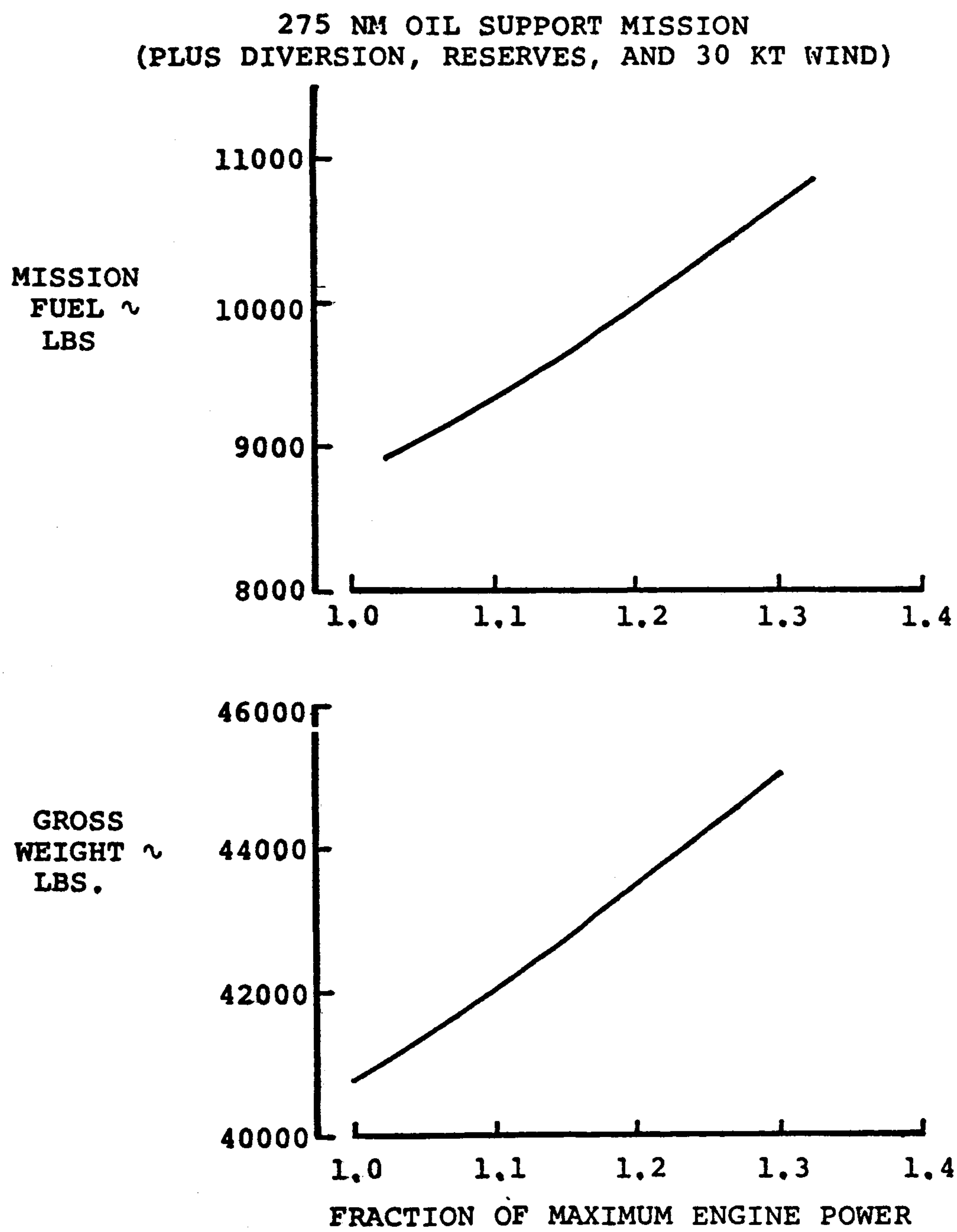
NATURAL RATING RELATIONSHIPS FOR CURRENT STATE-OF-THE-ART TANDEM

RATING	POWER RATIO	CRITERIA
OEI ON TAKEOFF	1.30	VTOL PINNACLE-TYPE TAKEOFF
LAND AFTER	1.53	VTOL WITH OEI/HOGE CAPABILITY
	1.24	1000-FT REJECTED TAKEOFF DISTANCE
FLYAWAY	1.21	3% CLIMB GRADIENT @ 45 KNOTS
OEI ENROUTE	1.00	150 FPM RATE OF CLIMB 1000 FEET ABOVE TAKEOFF SITE
TAKEOFF POWER (AEO)	.80	ALLOWS 15° NOSE DOWN ACCEL.
	.93	PROVIDES HOGE CAPABILITY 5000 FEET ABOVE CAT. A TAKEOFF SITE FOR EXTERNAL LOAD
MAXIMUM CONTINUOUS (OEI)	.83	PROVIDES 100-NMI OEI RANGE AFTER 30-MIN ENROUTE SHP IS USED, WITH 45-MINUTE CRUISE RESERVES
MAXIMUM CRUISE (AEO)	.77	PROVIDES 150-KT CRUISE SPEED

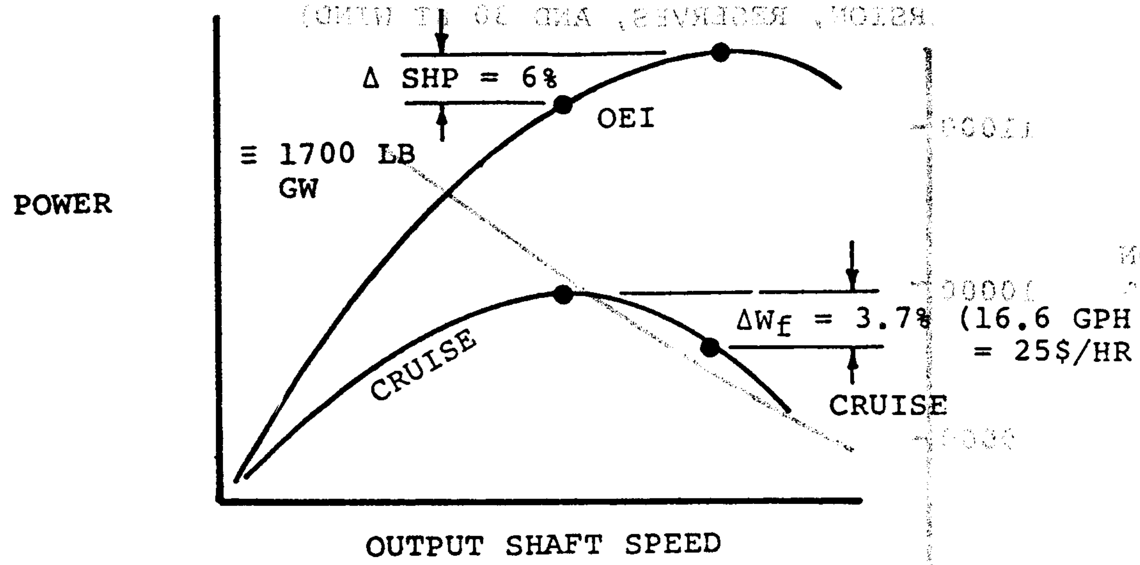
TAKE-OFF POWER AND DISTANCE

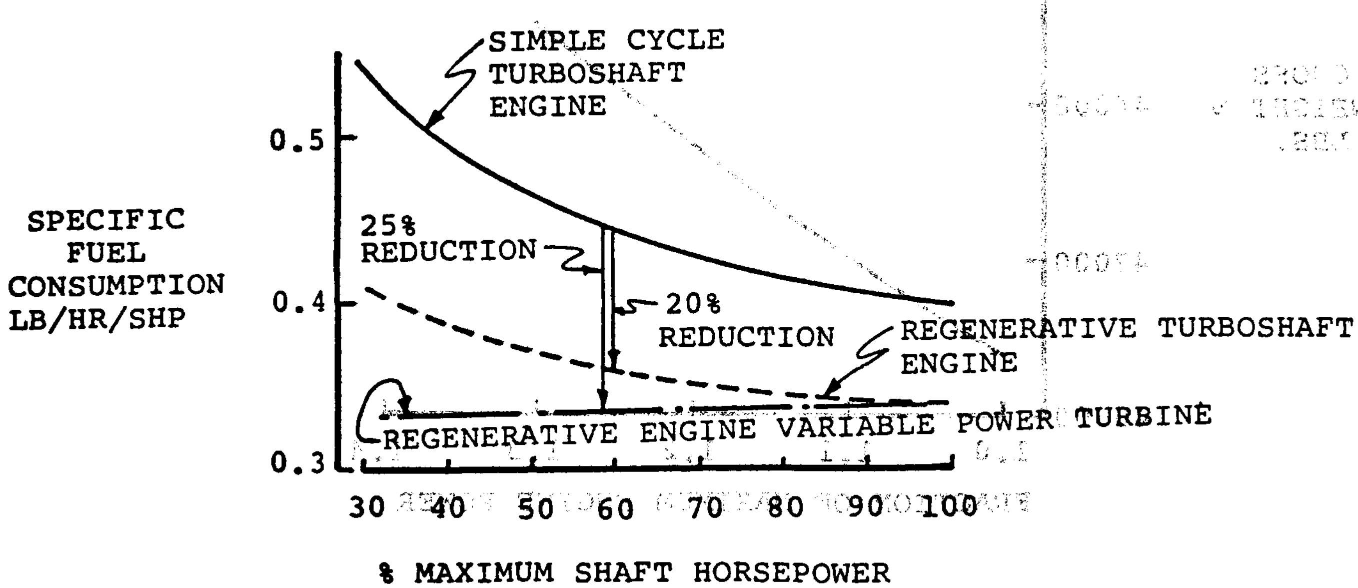


AIRCRAFT ENGINE OVERSIZE EFFECTS



FUEL CONSUMPTION





ENGINE GROWTH

- ROTORCRAFT WEIGHT AND POWER REQUIREMENTS GROW WITH TIME
  - WEIGHT GROWTH/PERFORMANCE SHORTFALLS DURING DEVELOPMENT
  - INCREASED MISSION EQUIPMENT
  - NEW OR EXTENDED MISSIONS
  - NEW MODELS
- FIRST GENERATION TURBOSHAFTS (T58, T64, T53, T55, PT6, ETC.) HAVE DOUBLED THEIR POWER WITHIN ORIGINAL FRAME. IT IS NOT CLEAR THAT NEWER TURBOSHAFT ENGINES COULD APPROACH THIS.
- GROWTH MIGHT BE IN DIRECTION OF HOTTER AMBIENT OR HIGHER ALTITUDES, WITH EMPHASIS ON THE SHORT TERM POWER SETTINGS.
- POWER RESTORATION BY MEANS OF WATER INJECTION MIGHT BE CONSIDERED, THOUGH ITS APPLICATION IS NOT AS CLEAR AS IT IS FOR THRUST ENGINES.
- COMPONENT MATCH FOR FLATTER TEMPERATURE LAPSE RATES MIGHT BE CONSIDERED.
- DESIGNING GROWTH INTO A NEW ENGINE WILL COMPROMISE THE ENGINE AND COULD BE A SEVERE DISADVANTAGE IN ANY COMPETITION FOR A POINT DESIGN.

ENGINE CONTROL FEATURES

- ISOCHRONOUS GOVERNING WITH ± 1% ROTOR SPEED CONTROL
- LESS THAN 5% ROTOR DROOP AFTER AUTOROTATIVE MANEUVER
- NO BEEP CONTROL NECESSARY
- AUTOMATIC LOAD SHARING WITHIN 2% OF ENGINE TORQUE
- INLET TEMPERATURE SENSOR TIME DELAY APPROXIMATELY 1 SECOND
- SIMPLE AUTOMATIC PUSHBUTTON ENGINE STARTING
- ADEQUATE INLET TEMPERATURE STALL MARGIN IN COMPRESSOR VARIABLE GEOMETRY TO TOLERATE EXHAUST REINGESTION

ENGINE SENSORS

O HIGH LEVEL BUFFERED SIGNALS DESIRABLE

O TORQUE SENSOR ACCURACY

- ACCURACY OF MEASUREMENT AND INDICATION INFLUENCE MARGINS NEEDED IN FIELD
- LARGE TOLERANCES COULD LEAD TO UNNECESSARY HIGH POWER CHECKS AND/OR MAINTENANCE
- ACCURACY AT DELIVERY, IN SERVICE, AND AFTER FIELD COMPONENT CHANGE NECESSARY

O MINIMIZE NUMBER OF LIMITS

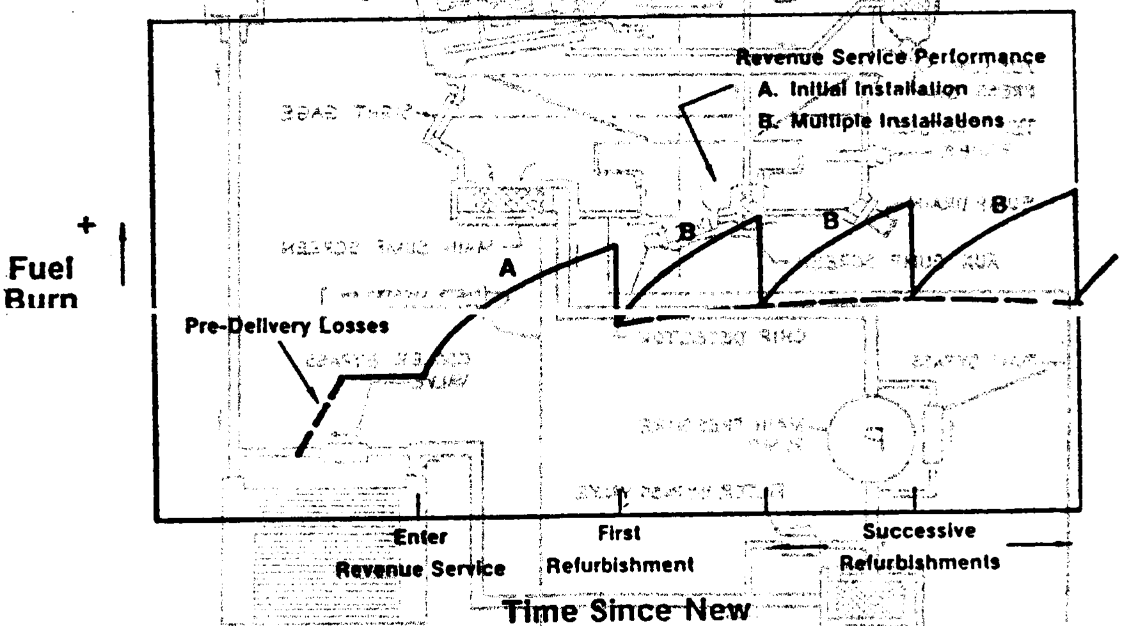
- 1 GAS GENERATOR SPEED LIMIT IF POSSIBLE (IF PTIT IS CRITICAL PARAMETER)
- 1 ENGINE TORQUE LIMIT (DRIVE SYSTEM ADDS OTHER TORQUE LIMITS)
- NO POWER LIMITS. COMBINATION OF TORQUE AND SPEED SHOULD BE ADEQUATE
- USE ROUND NUMBERS ON INSTRUMENTS. OTHERWISE, THE NEED FOR GREAT PRECISION IS IMPLIED.

INSTALLATION

- REDUCE ENGINE SKIN TEMPERATURES AND EMPLOY INTEGRAL HEAT SHIELDS TO MINIMIZE COMPARTMENT COOLING REQUIREMENTS.
    - RADIATION HEAT SHIELDS WILL BECOME A NECESSITY WITH THE INTRODUCTION OF COMPOSITE MATERIAL IN NACELLE CONSTRUCTION.
- ELIMINATE GROUND IDLE COOLDOWN REQUIREMENTS. COOLDOWN AT "FLAT" PITCH AND NORMAL ROTOR SPEED.

NASA ENGINE DIAGNOSTICS PROGRAM

Typical CF6-6D Performance Trends



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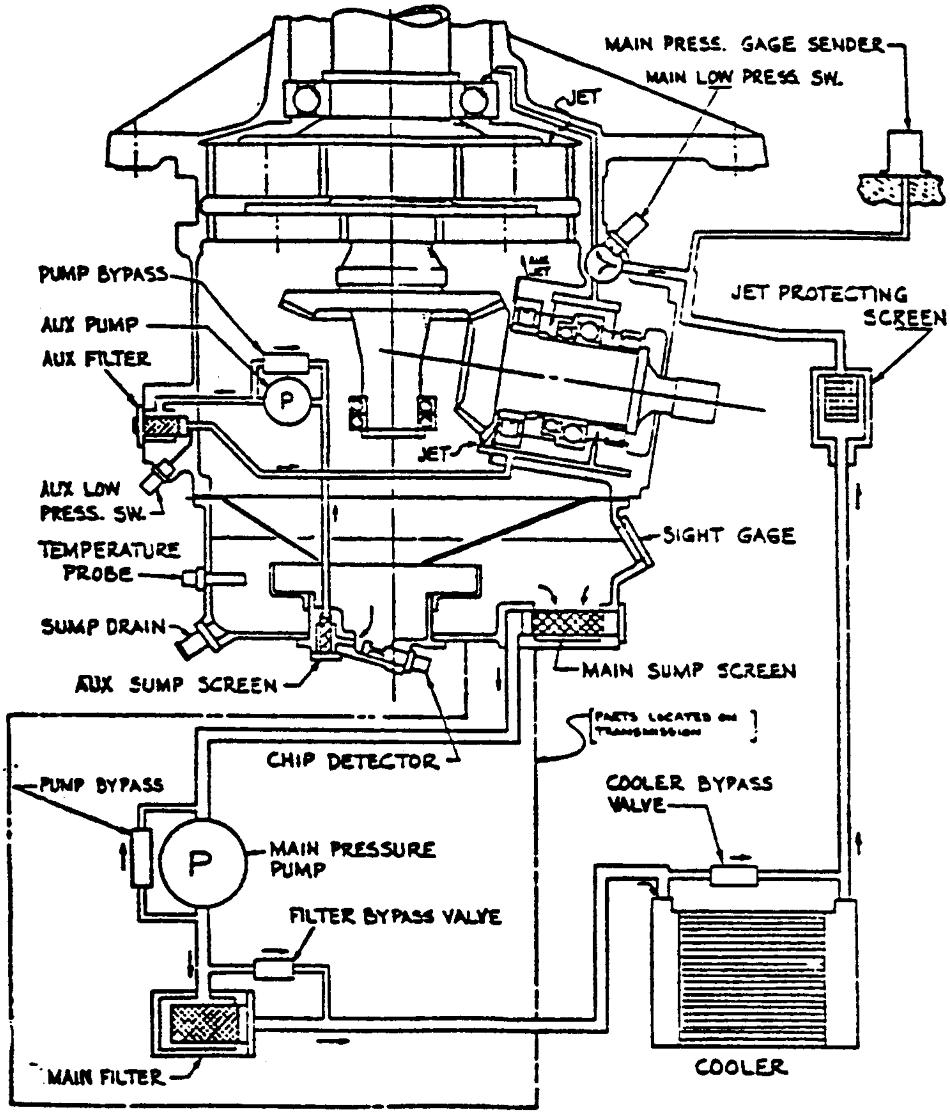
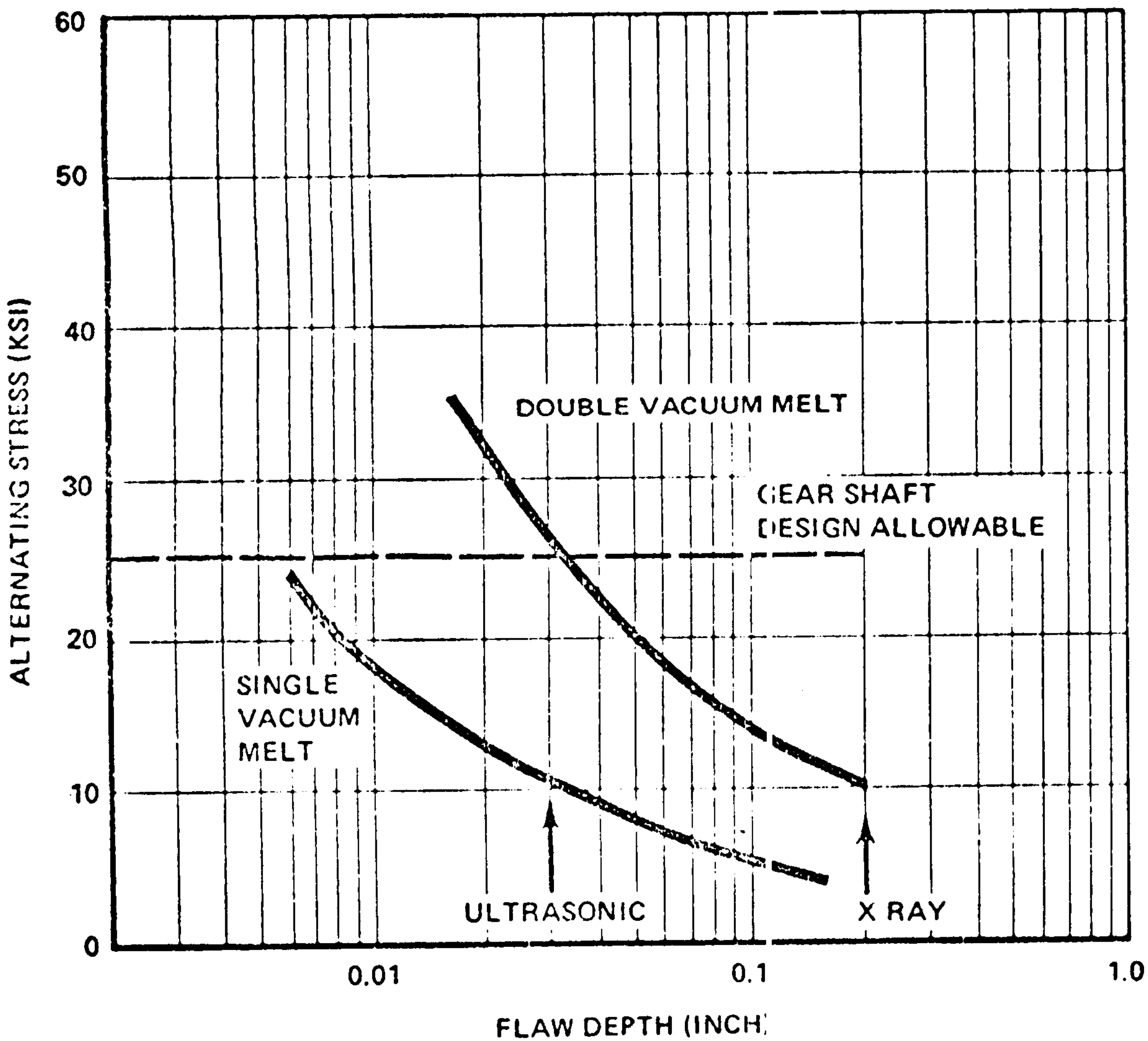
BACK-UP LUBRICATION



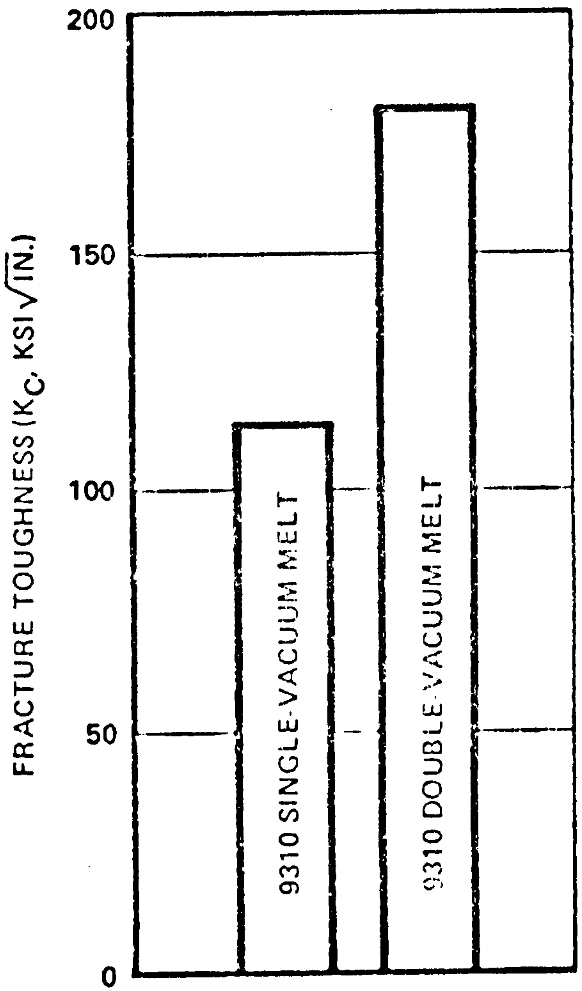
CHINOOK ADVANCED TECHNOLOGY

TRANSMISSION IMPROVEMENTS — 9310 GEAR STEEL

FATIGUE CRACK PROPAGATION THRESHOLD



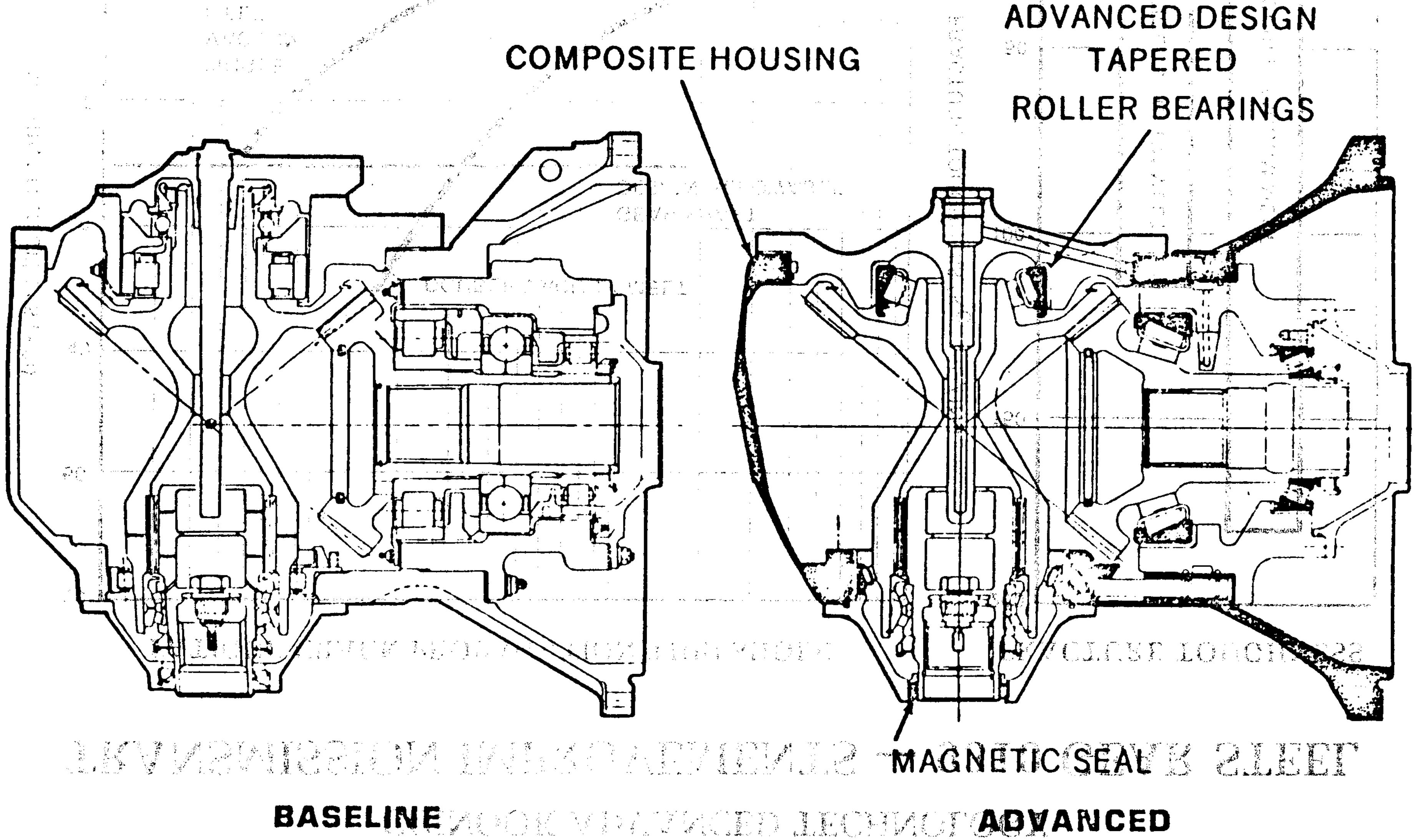
FRACTURE TOUGHNESS



100% ULTRASONICALLY INSPECTED

VERTOL COMPANY

THE ADVANCED GEARBOX ASSEMBLY IS LIGHTER, MORE RELIABLE, AND QUIETER



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PRESENTATION MATERIAL

USED BY

S. M. HUDSON

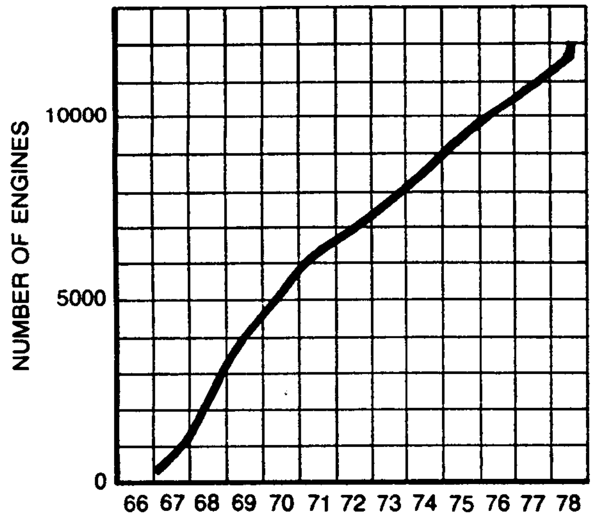
DETROIT DIESEL ALLISON

AT

HAA/NASA HELICOPTER WORKSHOP

EXPERIENCE

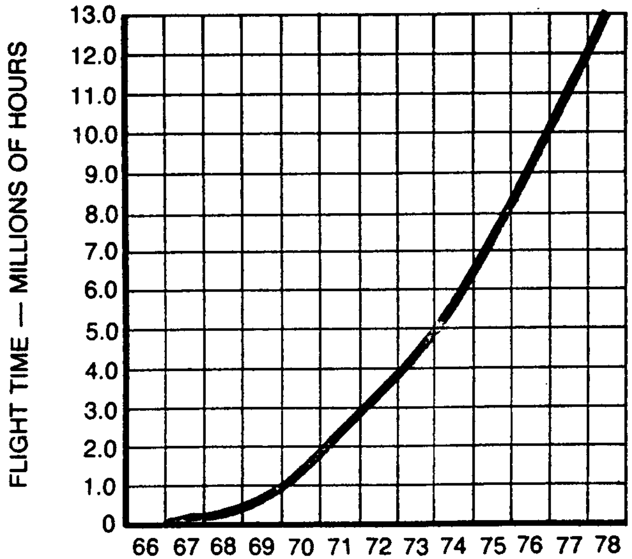
TOTAL 250 MODEL ENGINES PRODUCED



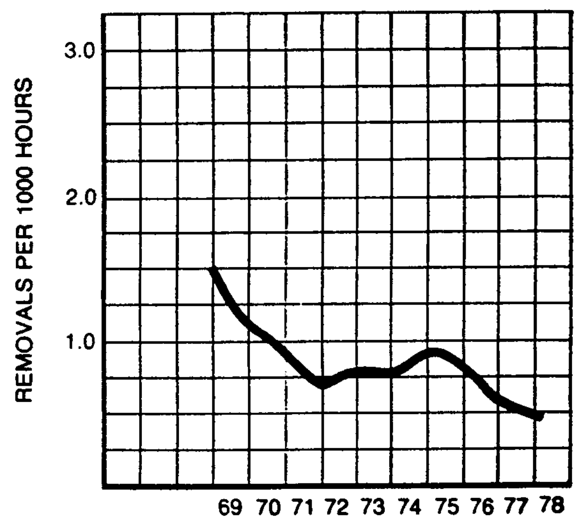
The new C28B, C28C and C30 engine models are the latest evolutionary development of the 250 engine family based on production engine experience of:

- 13,500,000 engine flight hours
- 12,000 production engines
- 1,400 customers

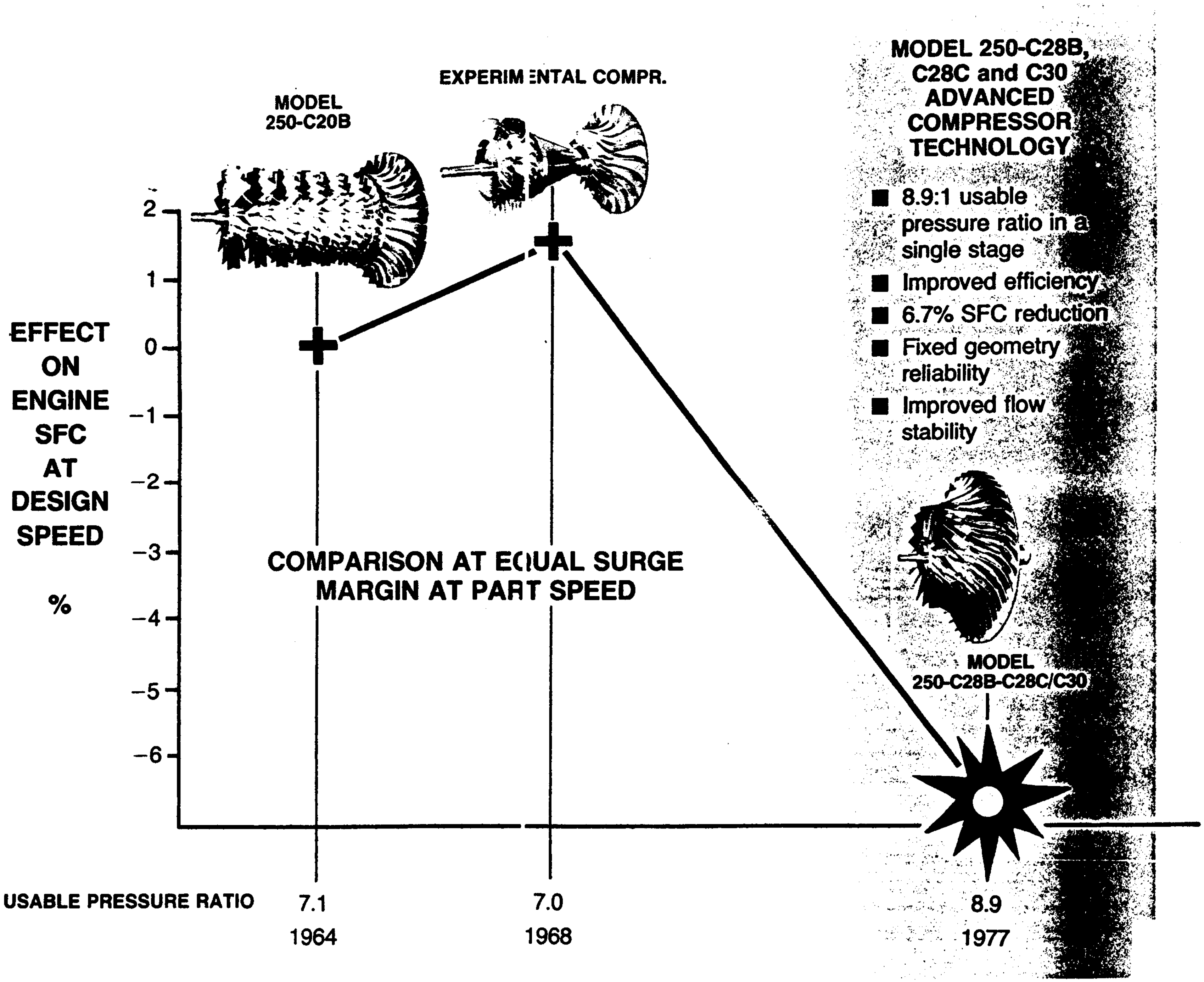
TOTAL OPERATIONAL TIME
ALL 250 ENGINES



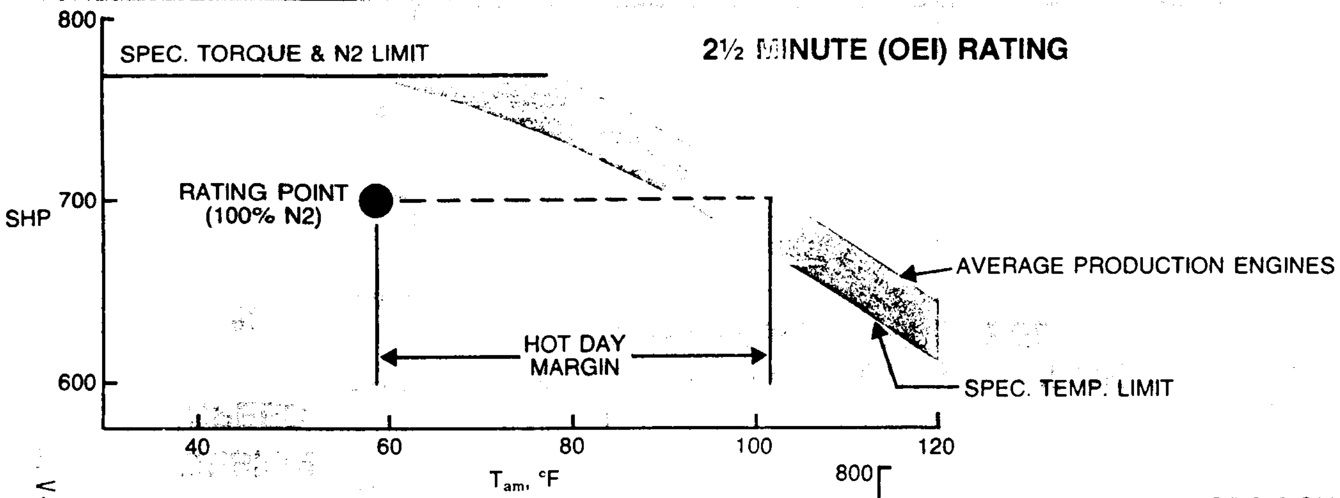
MILITARY AND COMMERCIAL ENGINE
COMPOSITE
PREMATURE REMOVAL RATE

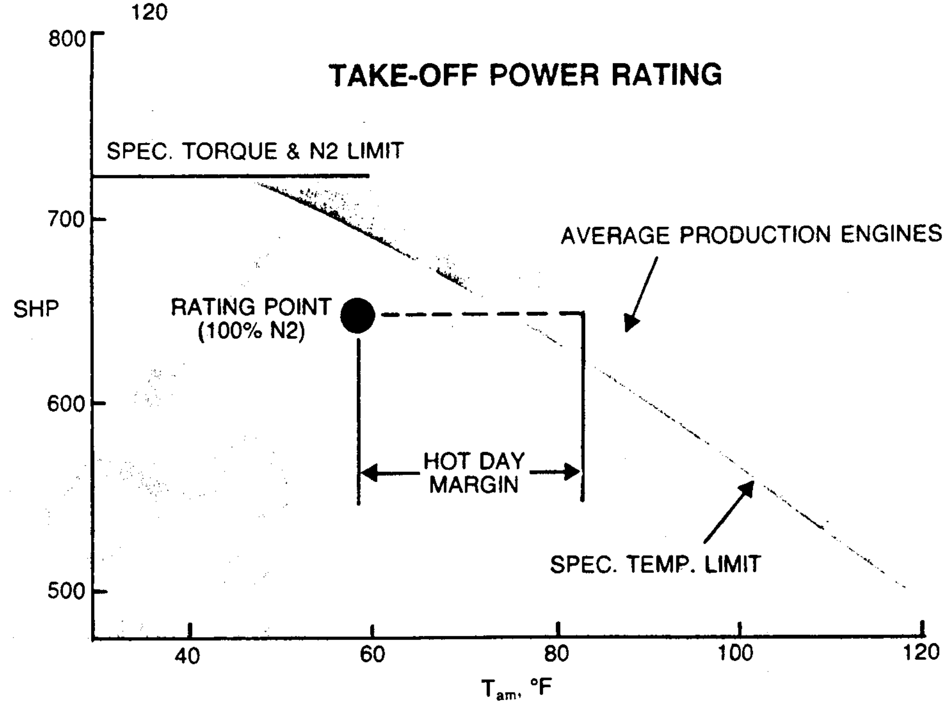


ADVANCED TECHNOLOGY COMPRESSOR DEVELOPMENT



250-C30 SEA LEVEL PERFORMANCE





Every **"650 hp"** production C30 engine provides at least

- **760 hp for 2½ min OEI up to 59°F**
- **700 hp for 2½ min OEI up to 90°F**
- **724 hp at T.O. up to 46°F**
- **690 hp at T.O. up to 59°F**
- **650 hp at T.O. up to 74°F**

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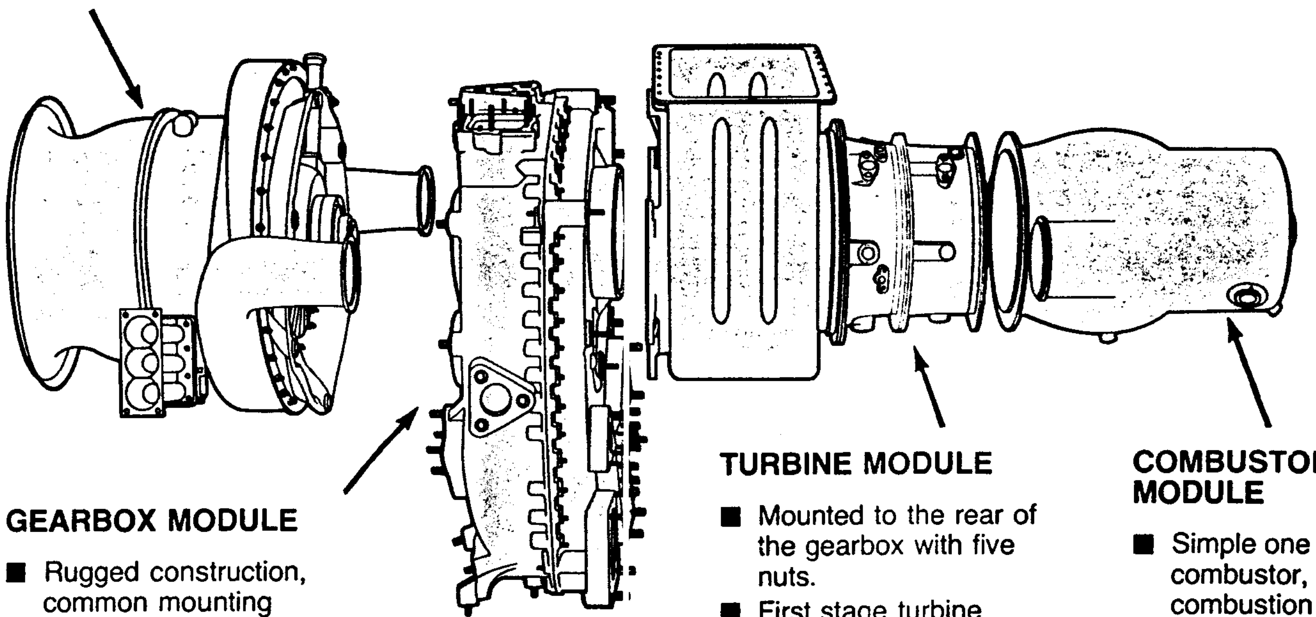
The proven m dular design with an initial 1500 hour TBO provides

- Less down time
- Less maintenance cost

COMPRESSOR MODULE
(with Air Particle Separator.)

- Ready for overhaul or repair by removing six gearbox mounting bolts.
- Simple single stage impeller.
- **No** variable geometry.



GEARBOX MODULE

- Rugged construction, common mounting pads for all model 250 engines.
- All lipseals changed externally.
- Rotating accessories use common nuts.
- **Both** front and rear drive.
- Easy access to the accessories for quick removal and replacement.

TURBINE MODULE

- Mounted to the rear of the gearbox with five nuts.
- First stage turbine accessible by removing combustor module. All accessories and shafting remain in place.

COMBUSTOR MODULE

- Simple one piece outer combustor, single combustion liner.
- Single fuel nozzle.
- Single split line for removal from turbine.
- Complete combustor system hardware can be inspected by removal of combustor module.

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Nick Hughes
AiResearch Manufacturing Company

MARKET PROJECTIONS

- 12.5-PERCENT GROWTH THROUGH 1990 FOR SMALL AND MEDIUM HELICOPTORS
- 80 PERCENT WILL BE IN 2, 4, AND 6 PLACE SIZE REQUIRING SINGLE OR TWIN ENGINES IN 300 TO 500 SHP CLASS

23–SVG1225–3

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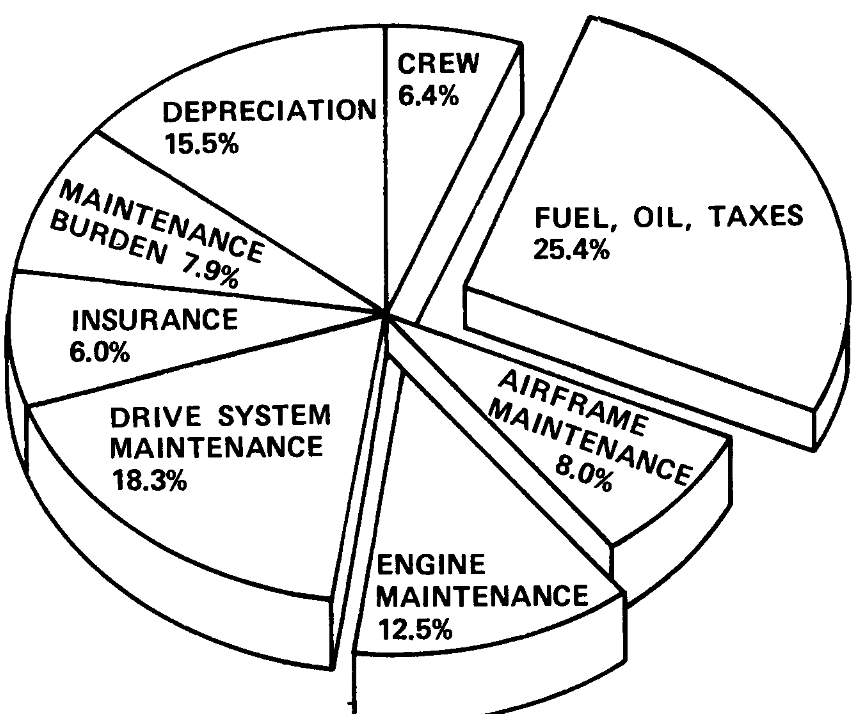
ENGINE TECHNOLOGY

SYSTEM DOC (FUEL = $1.00/GAL)



<u>TECHNOLOGY EMPHASIS</u>

FOR EFFICIENCY

- COMPONENT PERFORMANCE
- HIGH-CYCLE PRESSURE
- HIGH-CYCLE TEMPERATURE

FOR DURABILITY

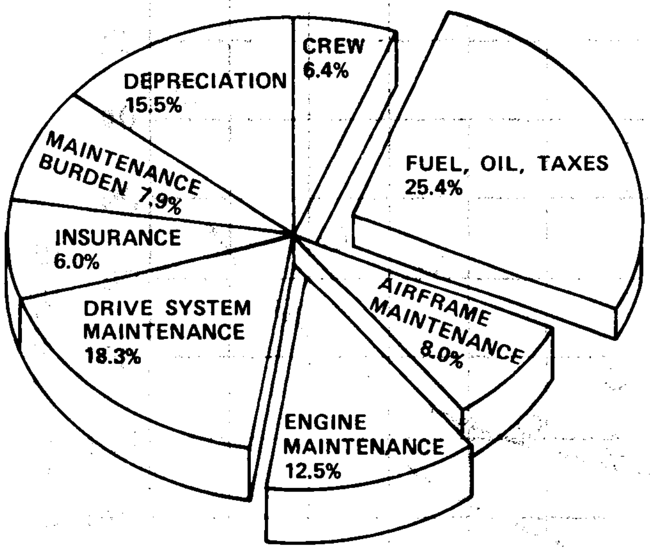
- MANUFACTURING
- LIFE PREDICTION
- PROVEN MECHANICAL DESIGN

23-SVG1225-21

DIRECT OPERATING COSTS

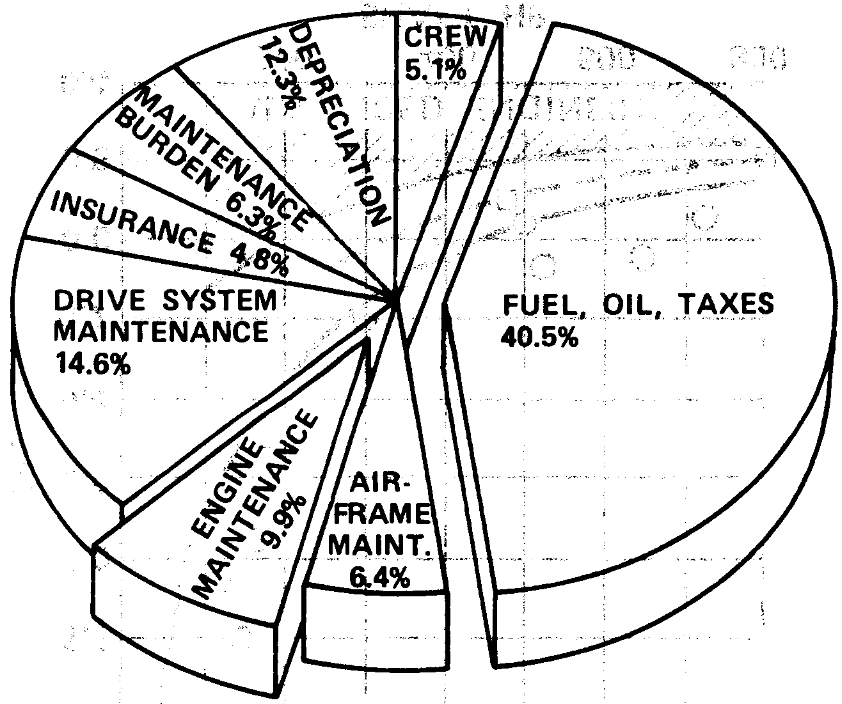
(CURRENT TECHNOLOGY SYSTEM)

- EFFECTS OF FUEL PRICE



FUEL COST = $1.00/GAL.

D.O.C. = 1

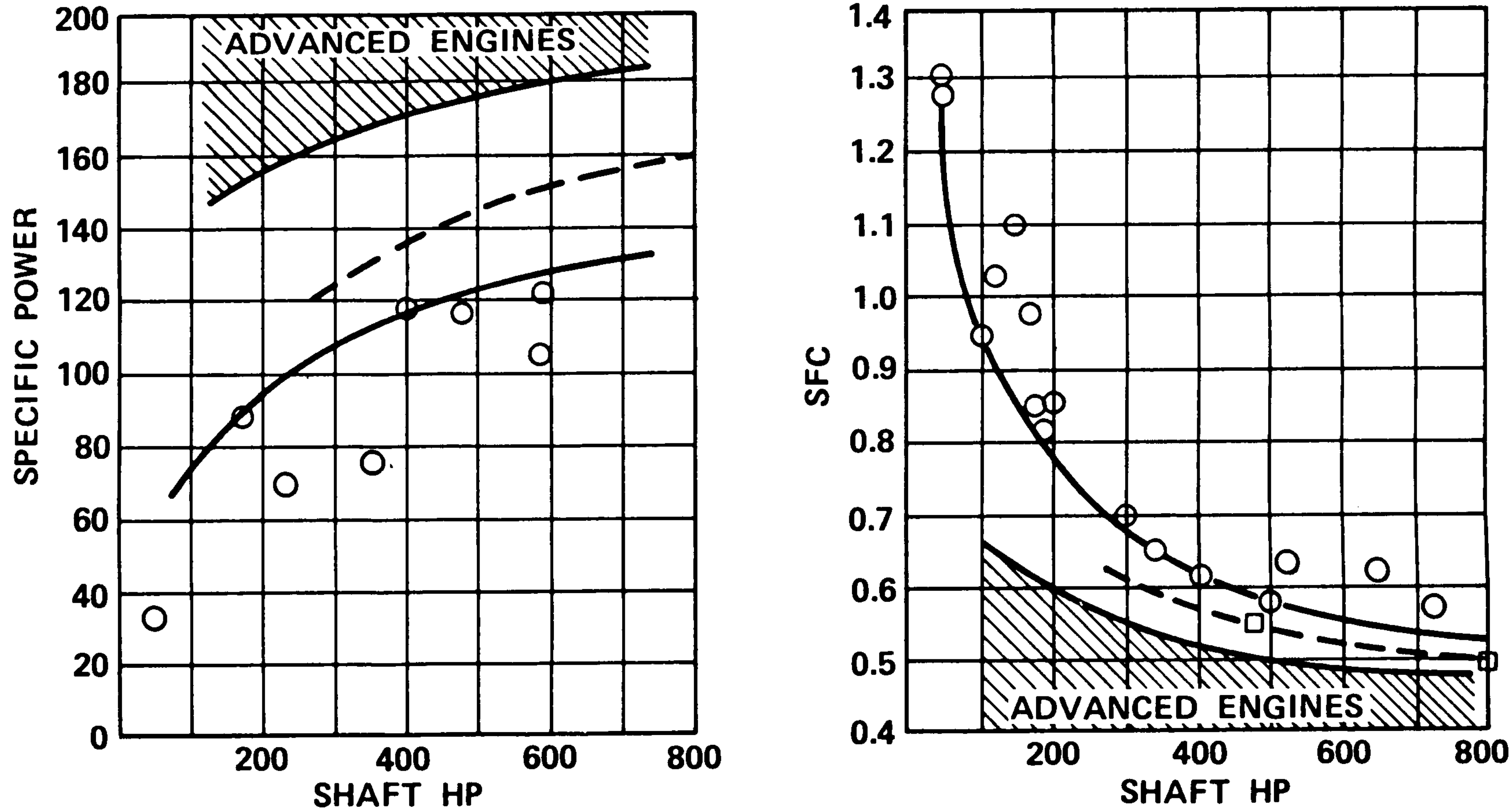


FUEL COST = $2.00/GAL

D.O.C. = 1.254

23-SVG1225-19

CURRENT VERSUS PROJECTED ENGINES



——— EXISTING ENGINES

– – – – DEMONSTRATOR ENGINES (1978 COMP TECHNOLOGY)

SHAFT POWER ENGINES (59°F, S.L.) PERFORMANCE

23–SVG1225–5

MANUFACTURING EFFECTS

- AXIAL TURBINE SCALING STUDY CONDUCTED FOR NASA (BLADE COUNT HELD CONSTANT)
  - ▲ EFFICIENCY DECREMENT AS ENGINE SIZE <u>DECREASES</u>

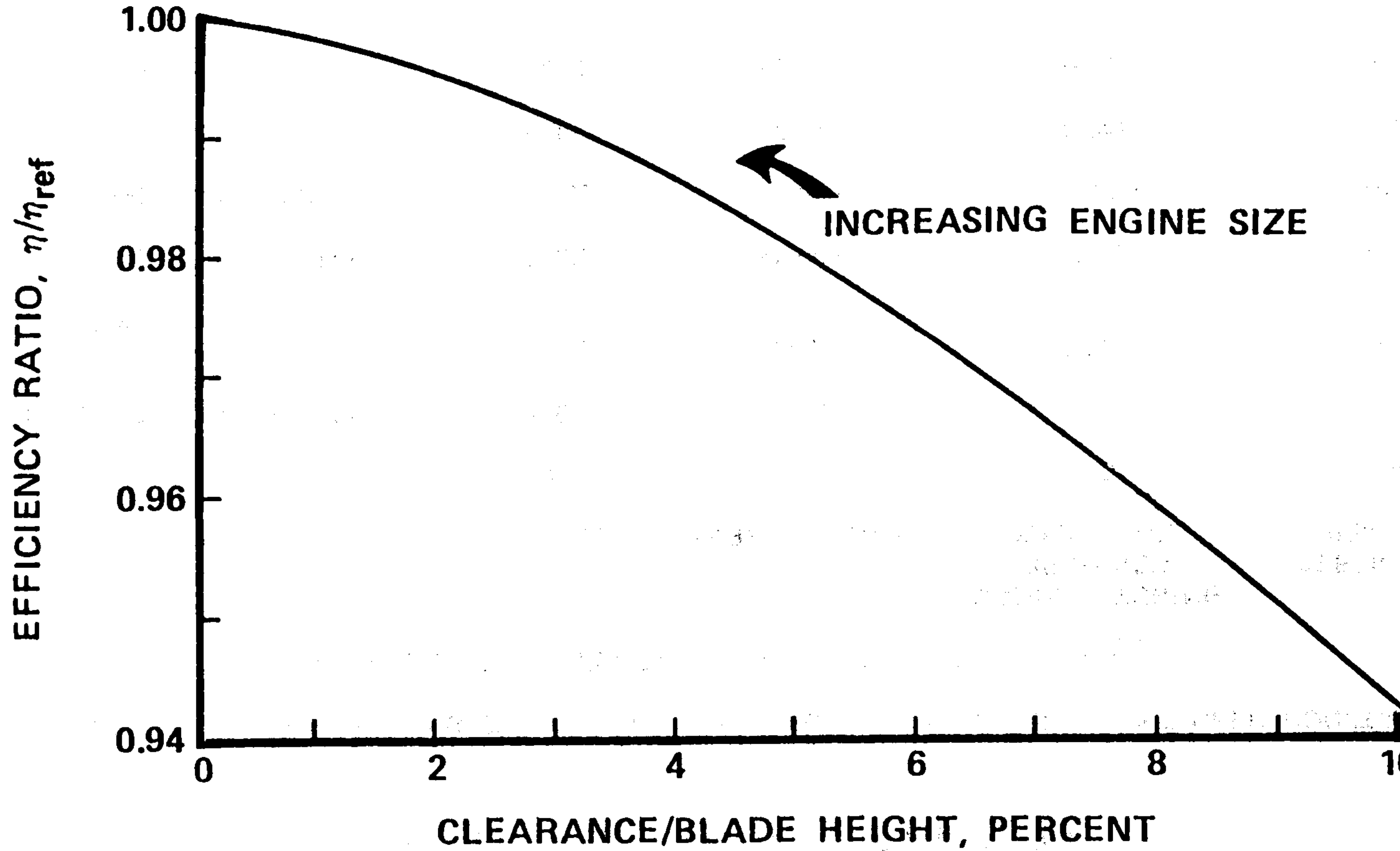
ITEM	FULL SIZE	DIRECT SCALE	MANUFACTURING REQUIRED TOLERANCE	*EFFICIENCY PENALTY
SCALE	1	0.3	0.3	–
CORRECTED FLOW (LBS/SEC)	6.5	0.59	0.59	–
TRAILING EDGE THICKNESS (IN.)	0.042	0.014	0.030	–1.0
AIRFOIL TOLERANCE (IN.)	±0.003	±0.001	±0.003	–0.7
FLOW-PATH TOLERANCE (IN.)	±0.005	±0.0015	±0.005	–0.5
FILLET RADIUS (IN.)	0.00	0.02	0.045	–0.44
TIP CLEARANCE (IN.)	0.013	0.0043	0.013	–3.64

*FROM FULL SCALE

23–SVG1225–2

CLEARANCE EFFECTS

- CLEARANCE LOSSES DECREASE AS ENGINE SIZE INCREASES



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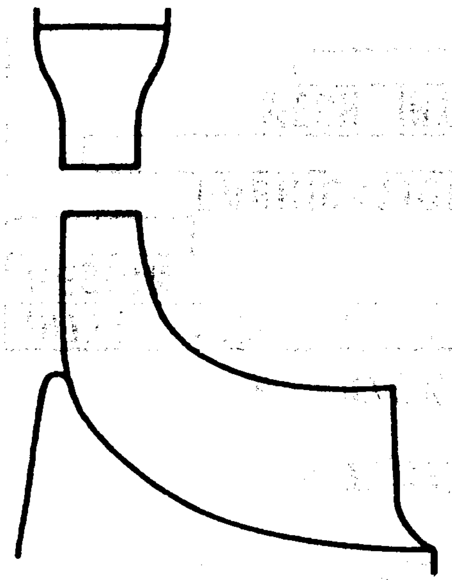
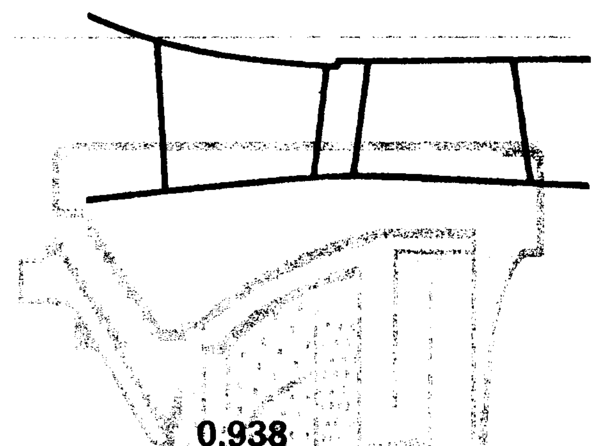
AXIAL-RADIAL HP TURBINE COMPARISON

$$\frac{W\sqrt{\theta}}{\delta} = 2 \text{ LB/SEC}$$





0.951	BASE EFFICIENCY	0.938
-0.036	CLEARANCE EFFECTS	-0.048
—	ASPECT RATIO EFFECTS	-0.044
-0.022	INCIDENCE EFFECTS	—
-0.005	MISCELLANEOUS EFFECTS	—
0.888	FINAL EFFICIENCY	0.846

23SVG1225-8

GARRETT

LAMINATED RADIAL TURBINE

OBJECTIVE: DESIGN AND DEMONSTRATE A COOLED LAMINATED RADIAL HP TURBINE ROTOR

- DESIGN POINT:

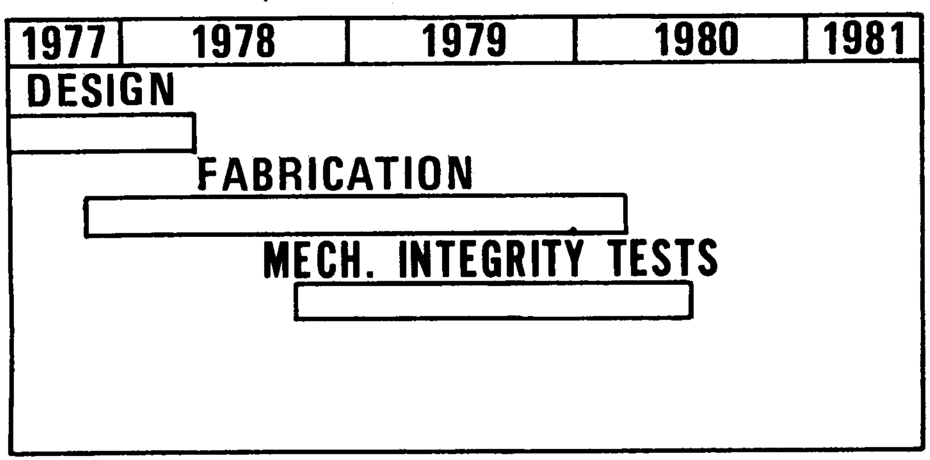
  TIT = $2300^{0}F$

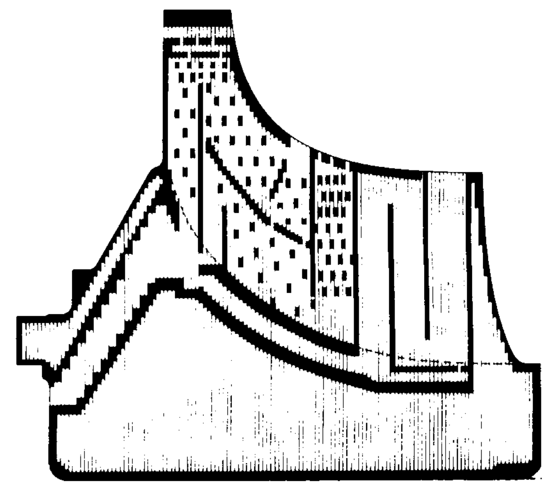
  P/P = 3.3

  $\frac{W\sqrt{\theta}}{\delta}$ = 0.633 LB/SEC

  N = 73,379 RPM

  η = 87.2%



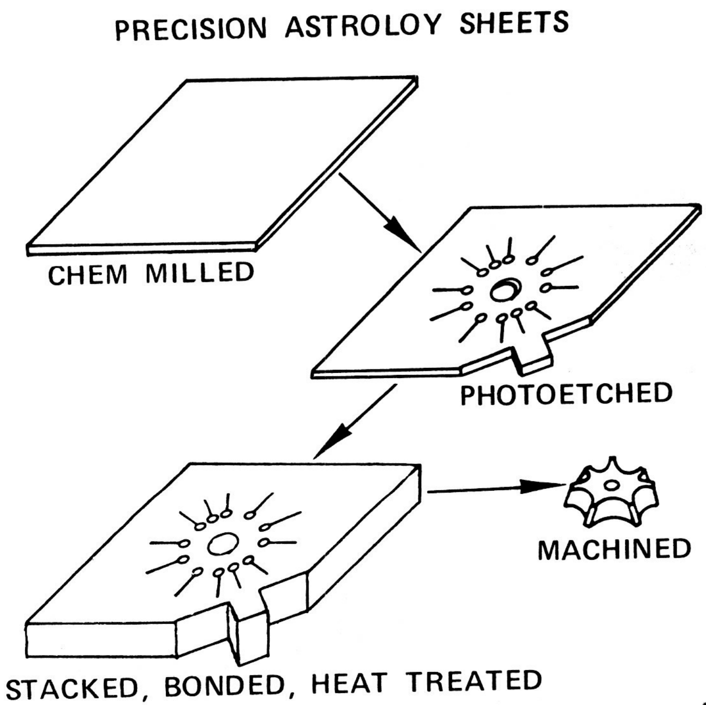


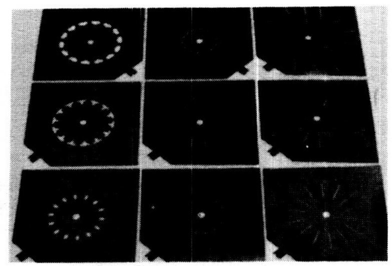
GARRETT

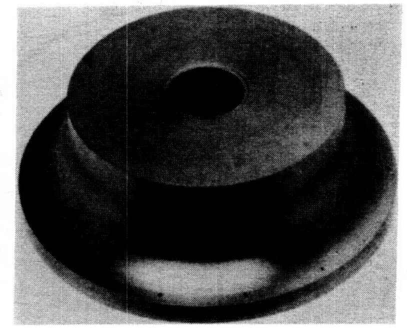
23-SVG834-29A

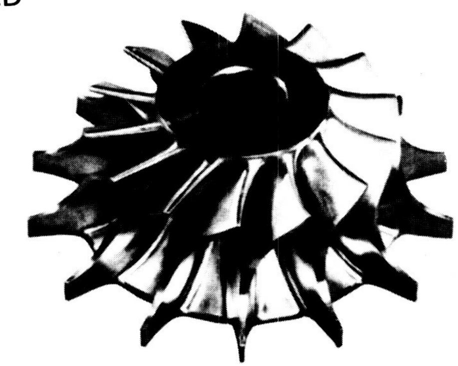
MP-75065

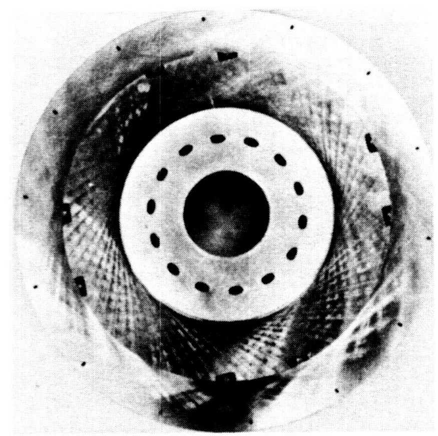
LAMINATED RADIAL TURBINE WHEEL











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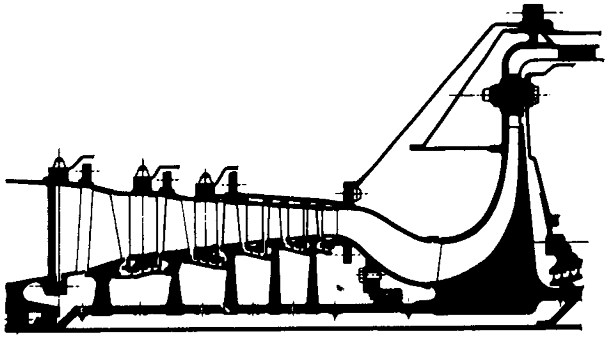
GARRETT

COMPRESSOR COMPARISON

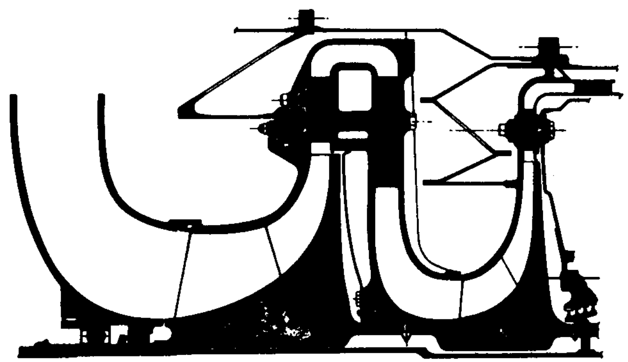
(300 TO 500 SHP CLASS)

SINGLE-SPOOL AXIAL/CENTRIFUGAL



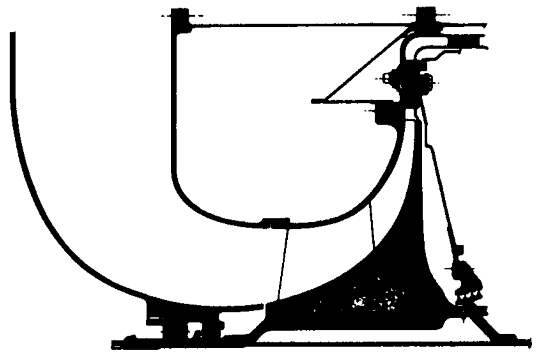
MS5757-50

TWO-STAGE CENTRIFUGAL



MS5757-51

SINGLE-STAGE CENTRIGUGAL



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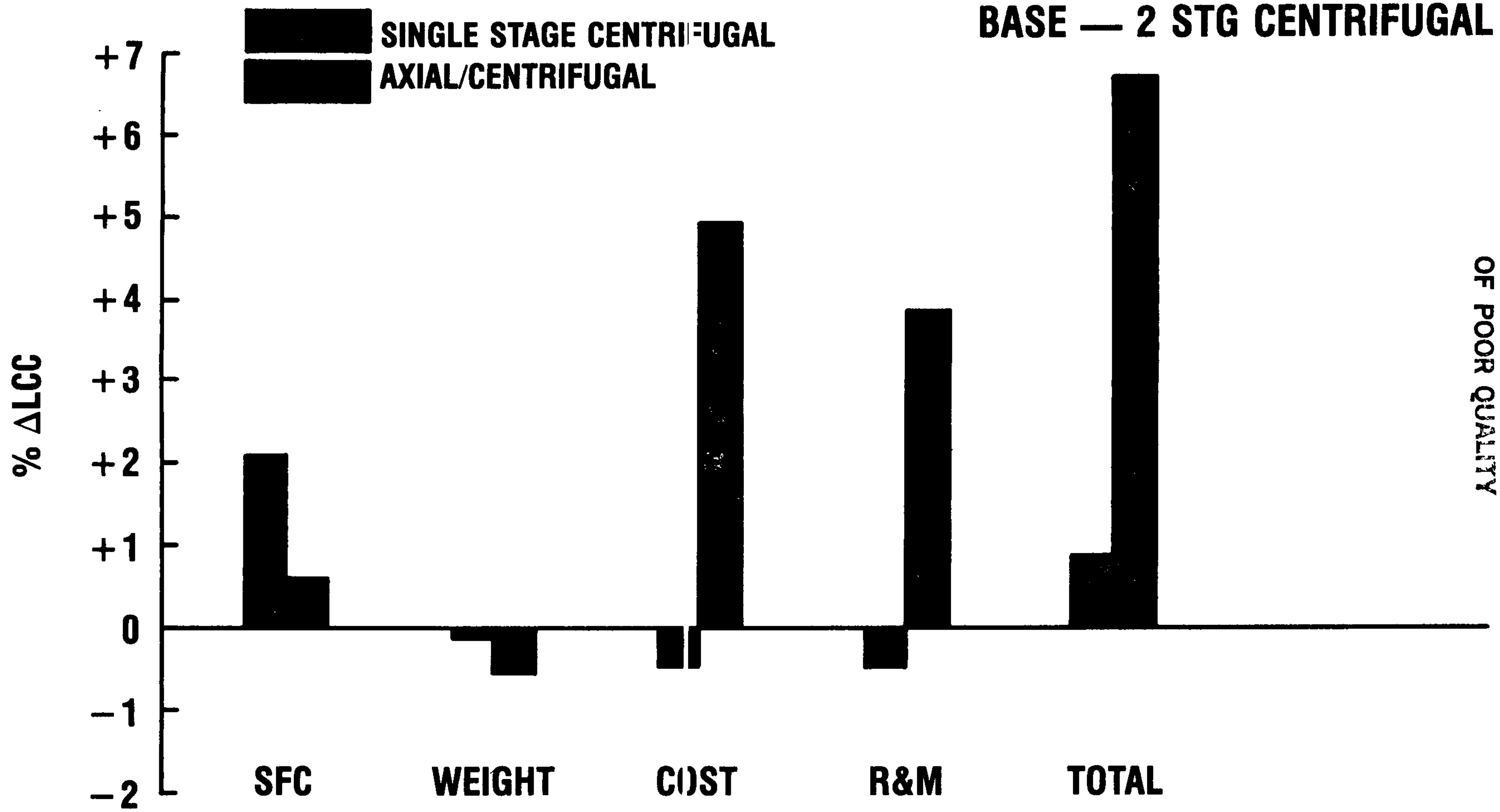
MP-75066

COMPRESSOR COMPARISON
(300-500 SHP CLASS)



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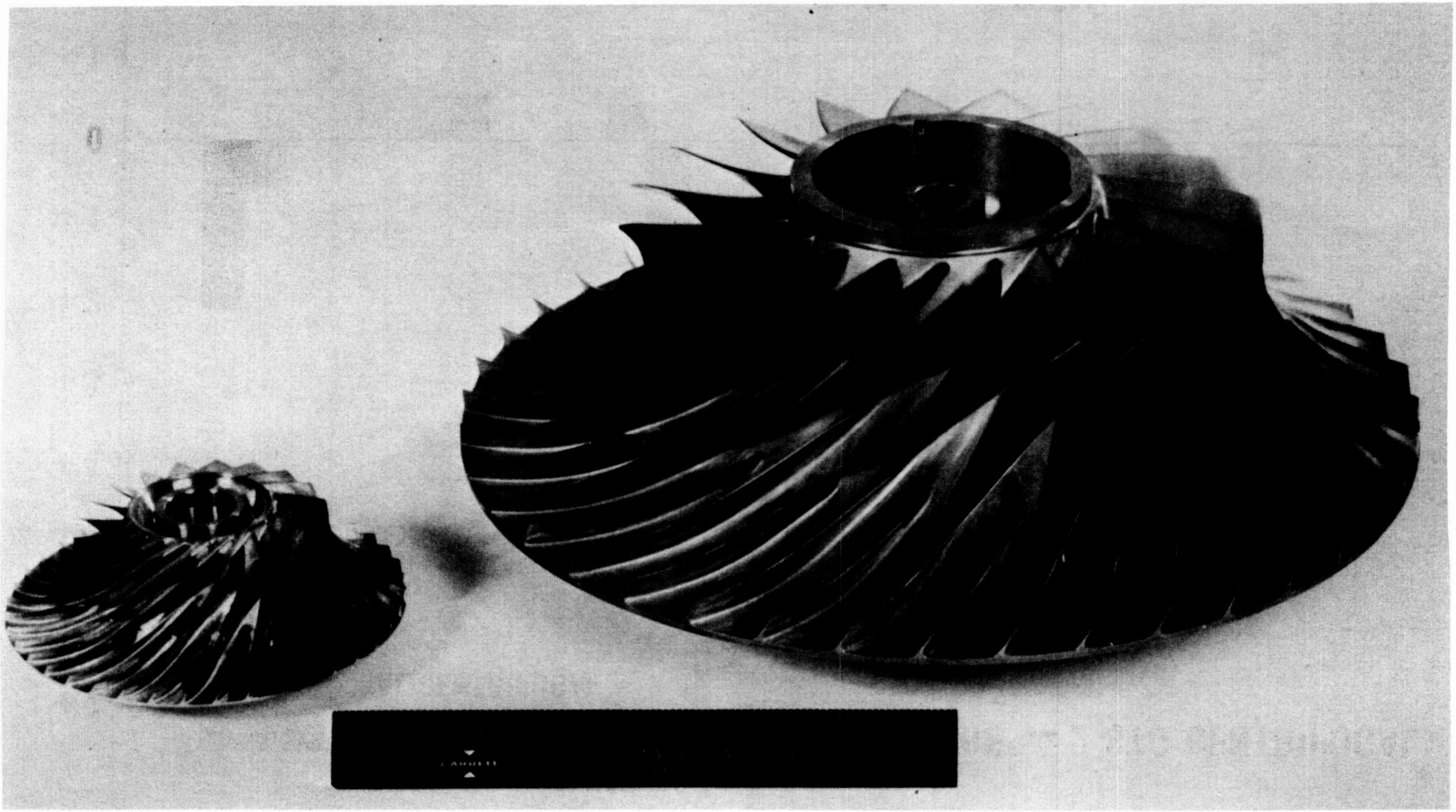
MP-75063

CENTRIFUGAL COMPRESSORS



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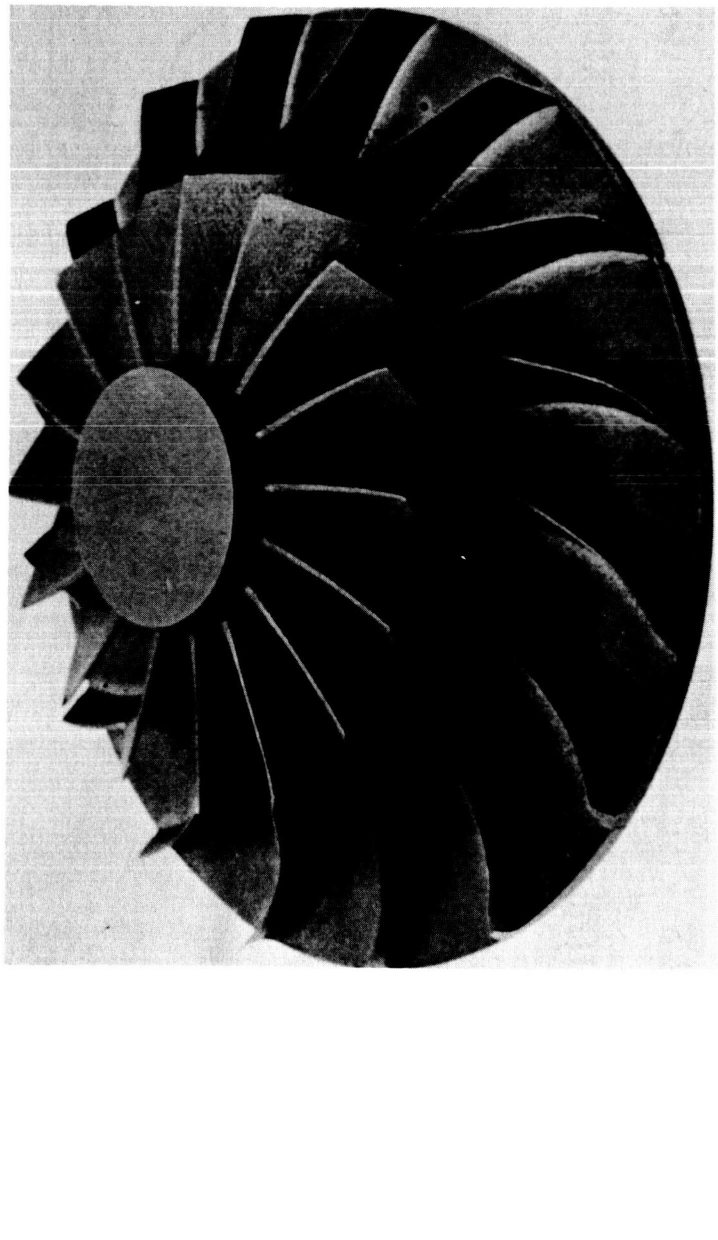
POWDER METAL TITANIUM



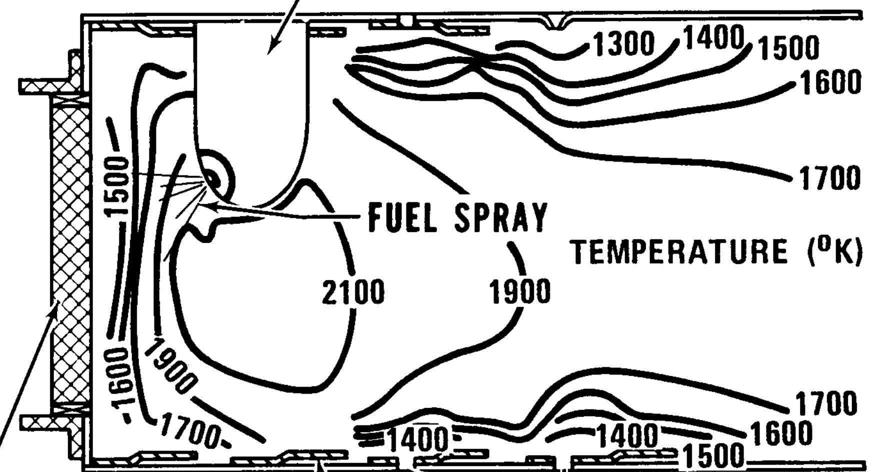
GARRETT

MP-75062

COMBUSTOR ADVANCED ANALYSIS

- DESIGN MODELS PREDICT
  - COMBUSTION EFFICIENCY
  - PATTERN FACTOR
  - LEAN BLOWOUT
  - FUEL DROPLET SIZE
  - FUEL SPRAY TRAJECTORY
  - WALL TEMPERATURES AND GRADIENTS
  - LINER LIFE
  - EXHAUST EMISSIONS

AMRDL COMBUSTOR ANALYSIS



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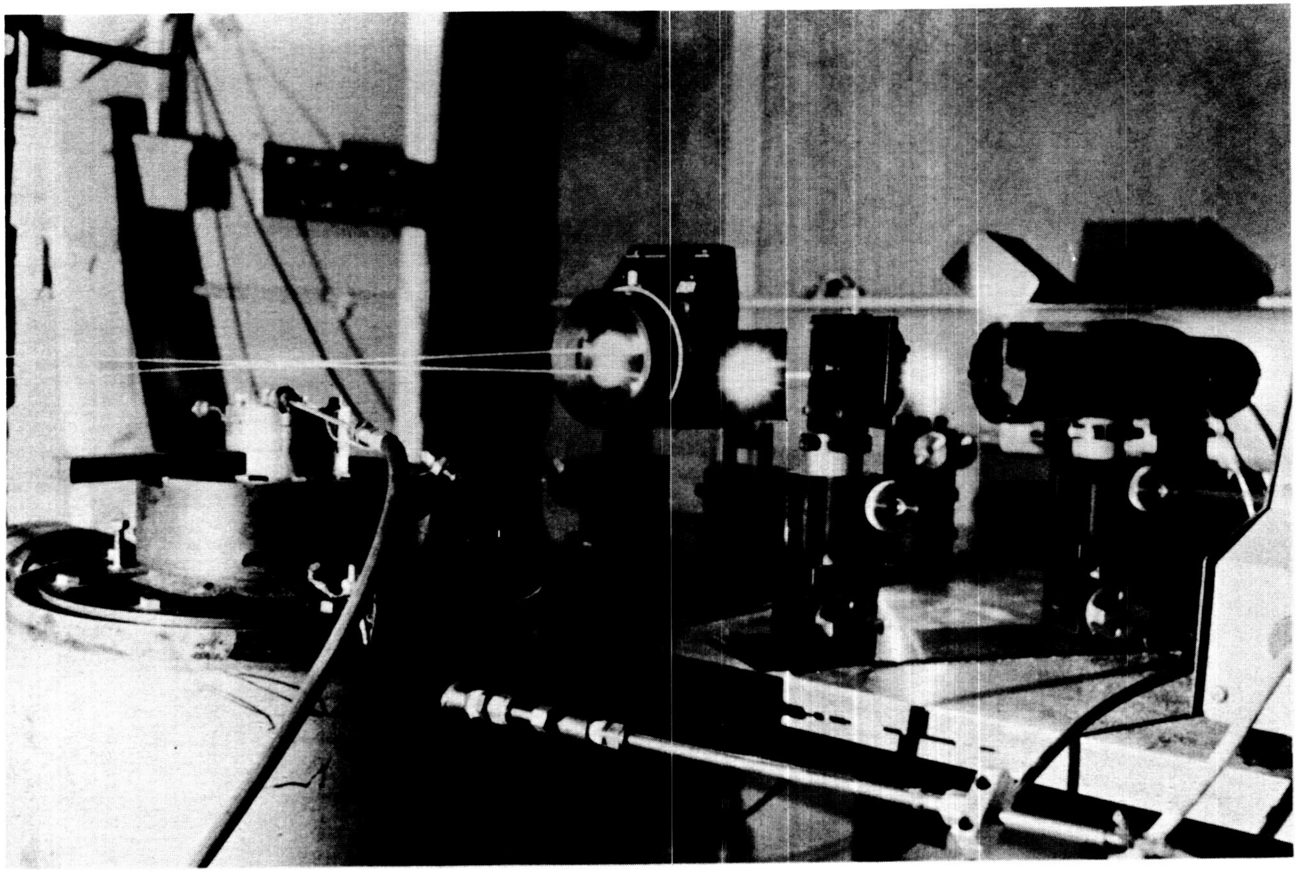
GARRETT 23-SVG620-9

LASER DOPPLER VELOCIMETER (LDV) SYSTEM



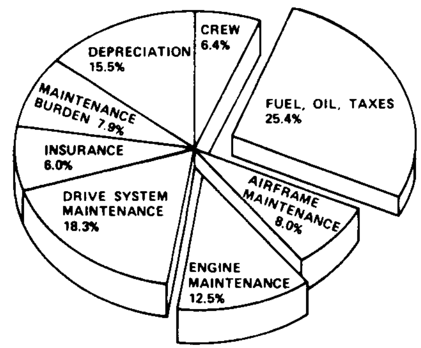
LDV SETUP ON CALIBRATED FLOW NOZZLE RIG

MS 4409-140

DIRECT OPERATING COST ESTIMATES

CURRENT VERSUS 1990 TECHNOLOGY
(6 PLACE HELICOPTER)

CURRENT ENGINE TECHNOLOGY



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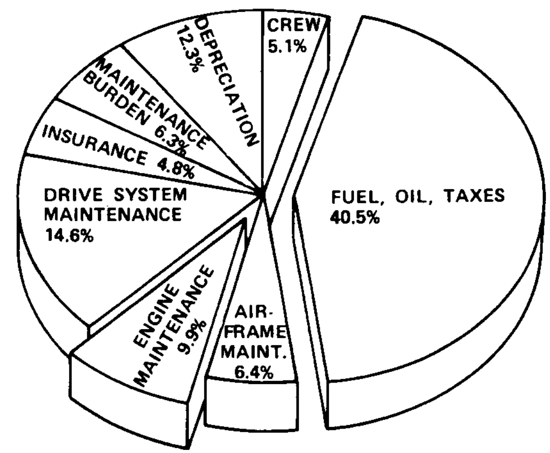
D.O.C. = 1.00



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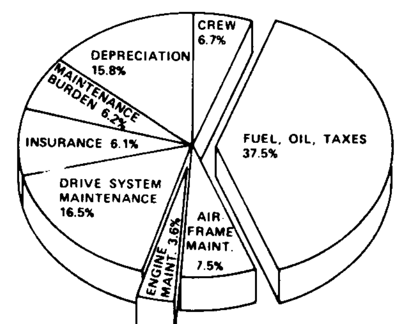
D.O.C. = 1.254 (1.00)

1990 ENGINE TECHNOLOGY



FUEL COST = \$2.00/GAL
D.O.C. = 0.96 (0.767)

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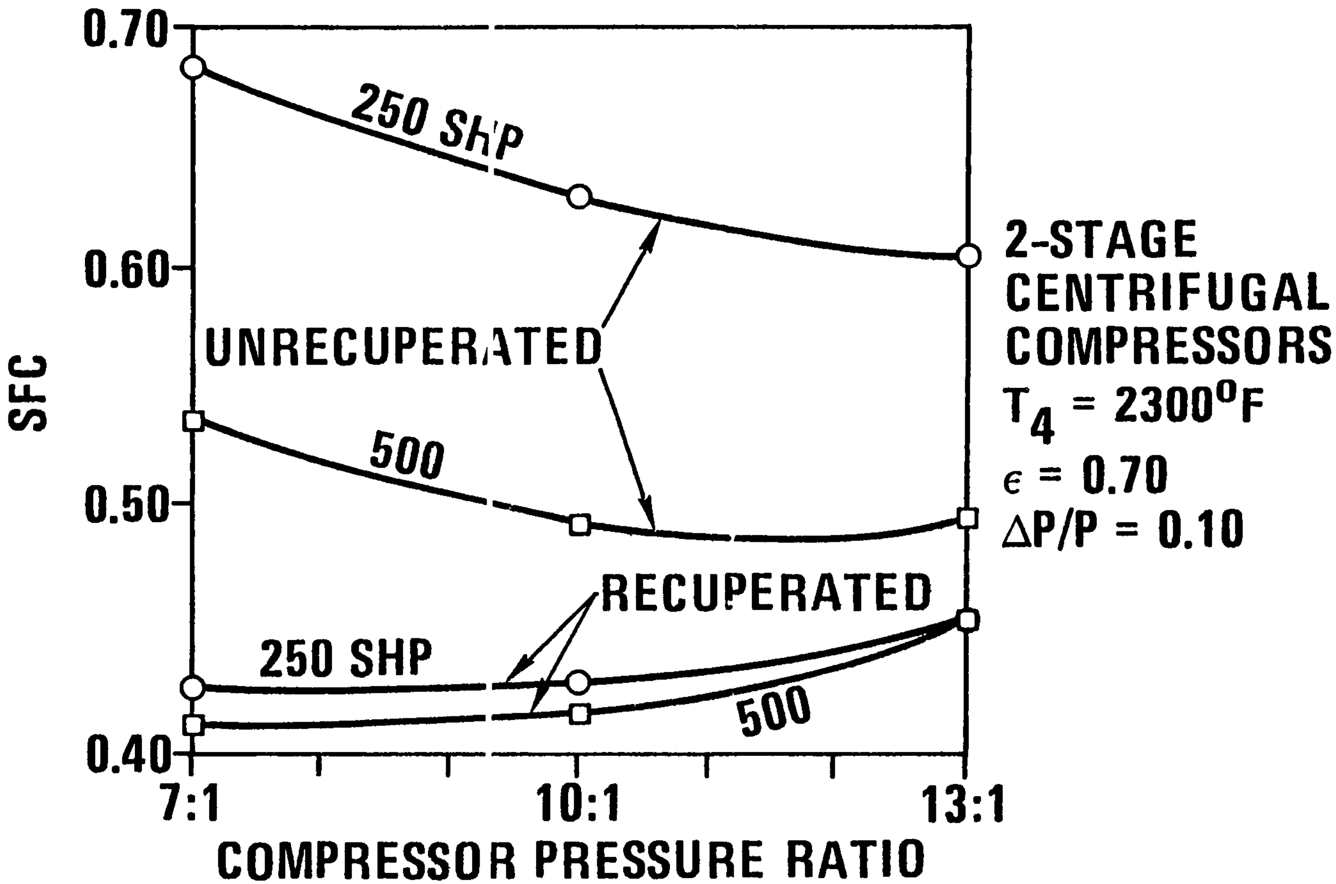
TURBOSHAFT ENGINES

RECUPERATED VS. UNRECUPERATED



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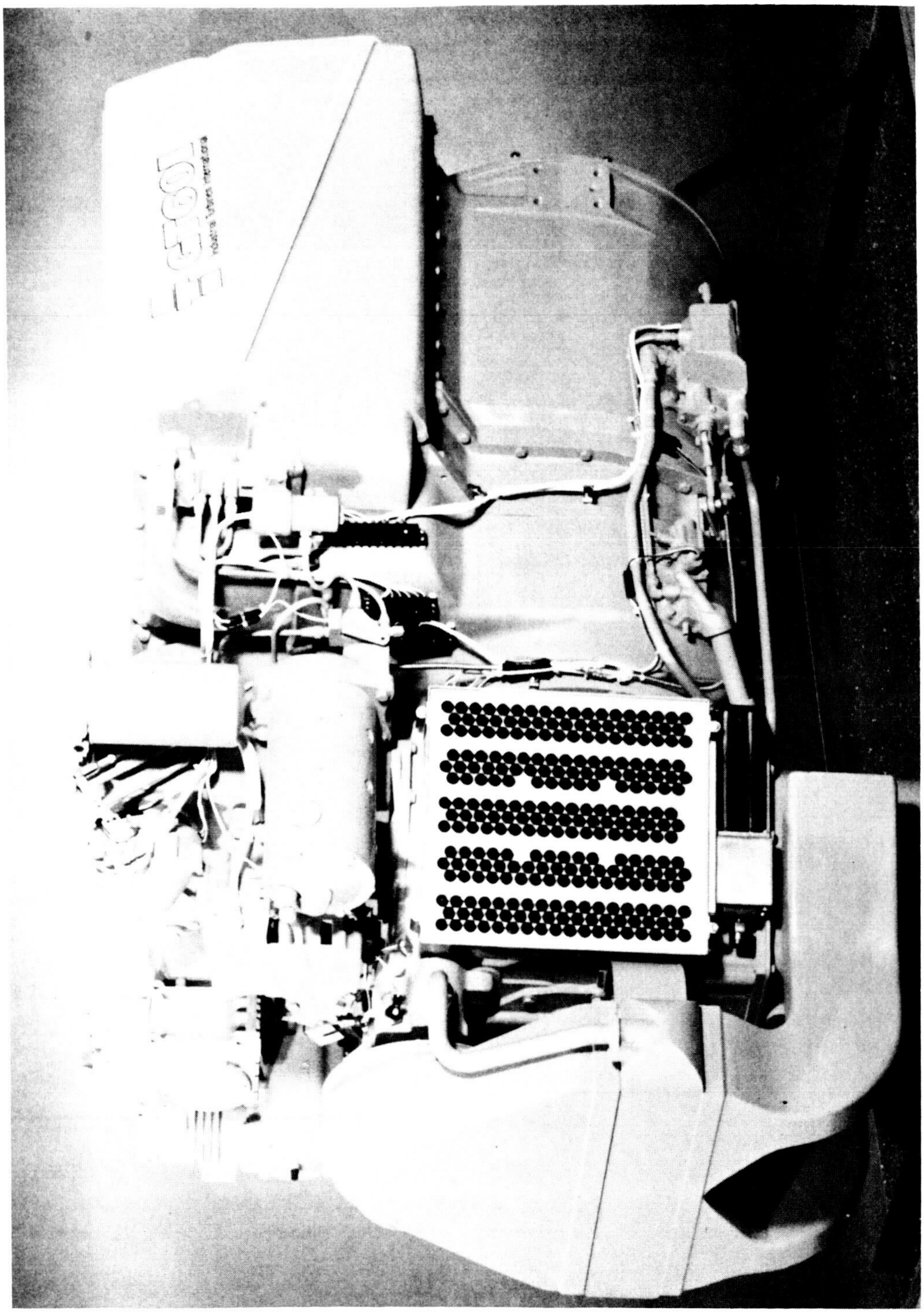
THE GT601



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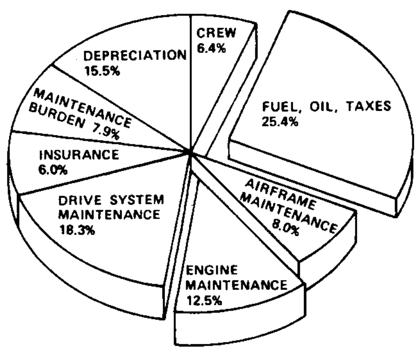
MP-75072

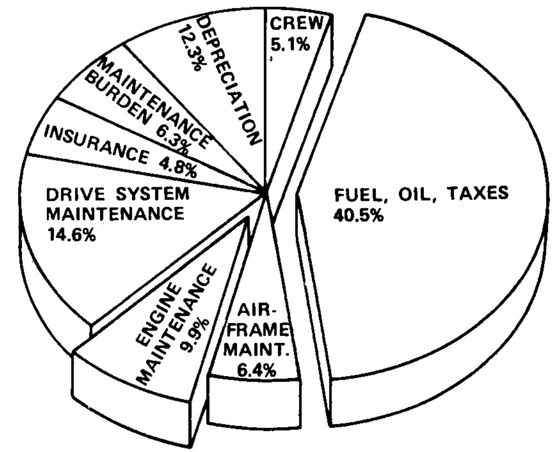
DIRECT OPERATING COST ESTIMATES

CURRENT VERSUS 1990 TECHNOLOGY
(6 PLACE HELICOPTER)

CURRENT ENGINE TECHNOLOGY

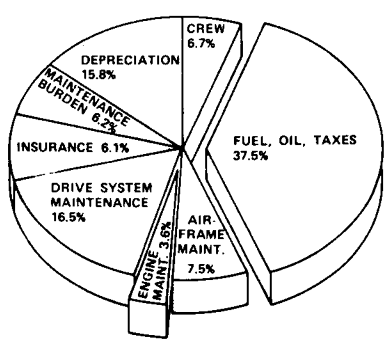


FUEL COST = $1.00/GAL
D.O.C. = 1.00



FUEL COST = $2.00/GAL
D.O.C. = 1.254 (1.00)

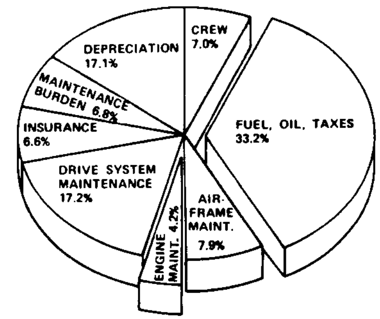
1990 ENGINE TECHNOLOGY



23-SVG1225-20

FUEL COST = $2.00/GAL
D.O.C. = 0.96 (0.767)

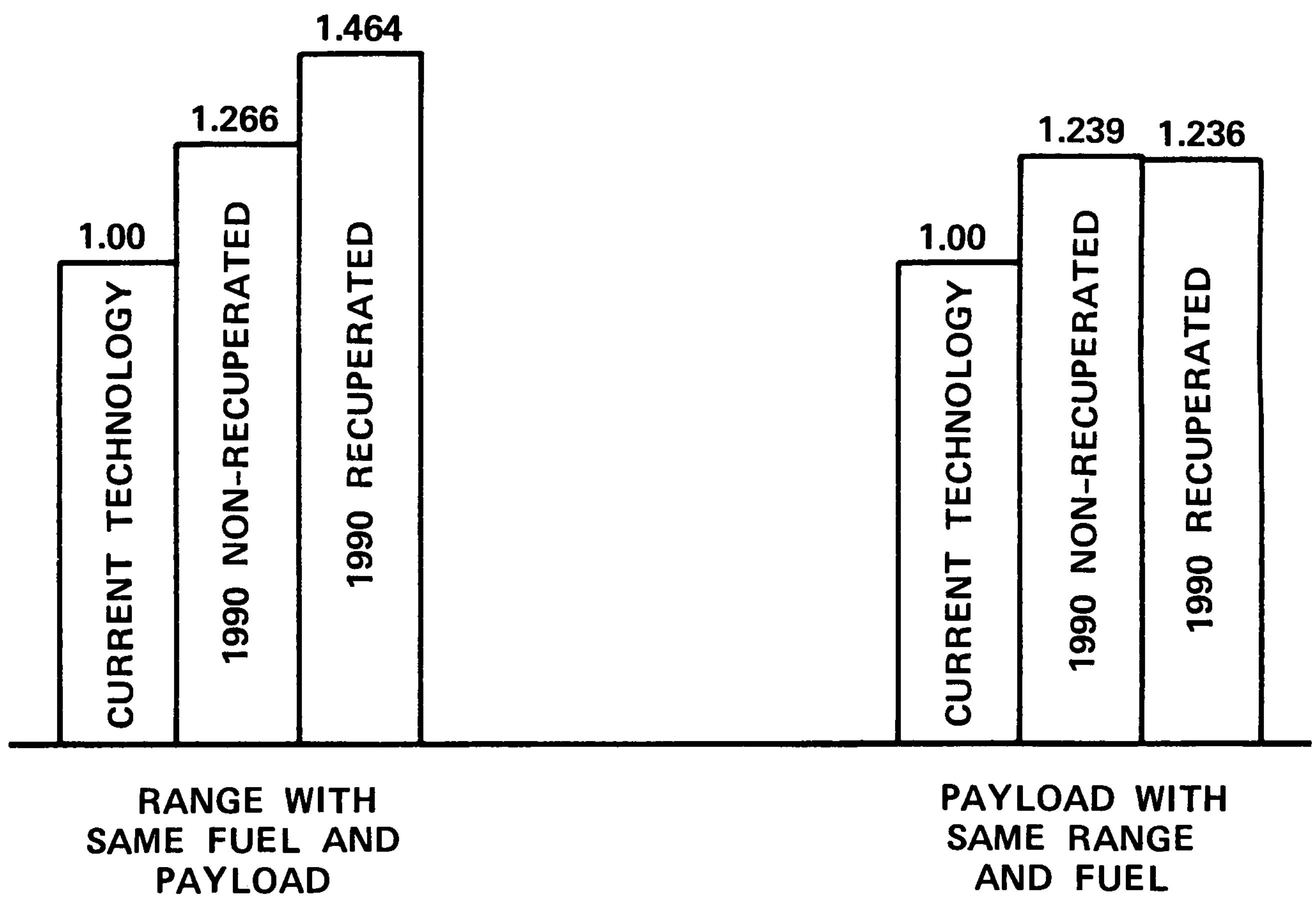
RECUPERATED ENGINE



FUEL COST = $2.00/GAL
D.O.C. = 0.919 (0.733)

ESTIMATED IMPACT OF TECHNOLOGY

6-PASSENGER HELICOPTER
CONSTANT GROSS WEIGHT



23-SVG1225-17

5955

TECHNOLOGY EMPHASIS FOR FUTURE

- ROTORCRAFT ENGINE STUDY
- COMPRESSORS
  - 3-D AERODYNAMICS
  - INSTRUMENTATION
- COMBUSTORS
  - LINER COOLING
  - COATINGS
  - HEAT-TRANSFER RIG
- TURBINES (LAMINATED)
  - MATERIAL QUALITY (SHEETS)
  - BONDING TECHNIQUES
  - HEAT-TRANSFER CODES
- RECUPERATORS
  - WEIGHT, SIZE, COST
- CONTROLS
  - PILOT WORKLOAD VERSUS SOPHISTICATION
  - ELECTRONIC VERSUS MECHANICAL
- DURABILITY
  - FRACTURE MECHANICS FOR CAST STRUCTURE
- MAINTAINABILITY
  - MODULAR DESIGN
  - EASE OF INSPECTION

23–SVG1225–1

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TAKE OFF and EMERGENCY POWER RATINGS

CAT 'A' OPERATIONS = MORE EMERGENCY POWER

POWER PAIRS

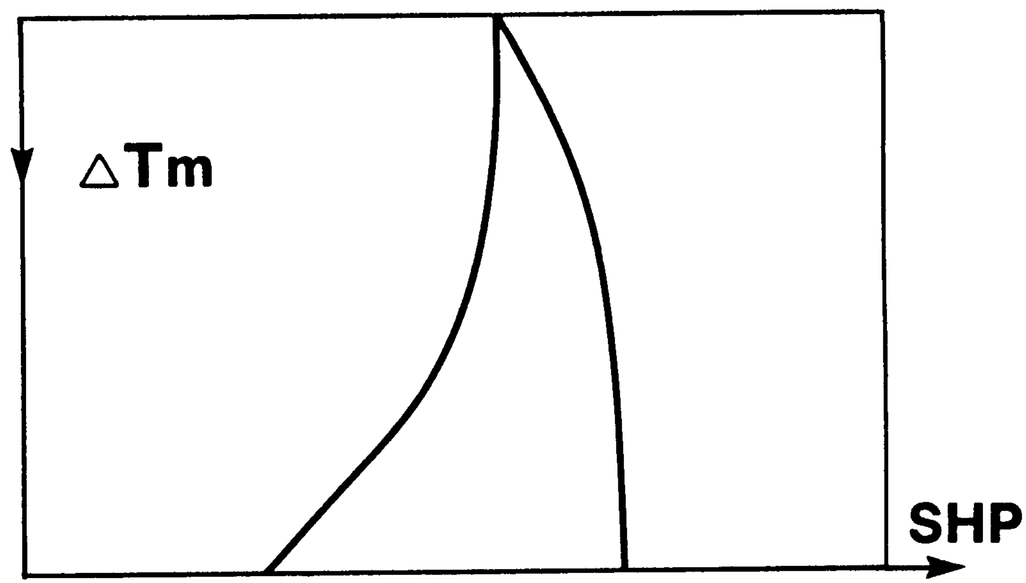
A rational choice of take-off and emergency power ratings.

C 1180 11187

BACKGROUND

Stress level
ΔTm
creep data
test times

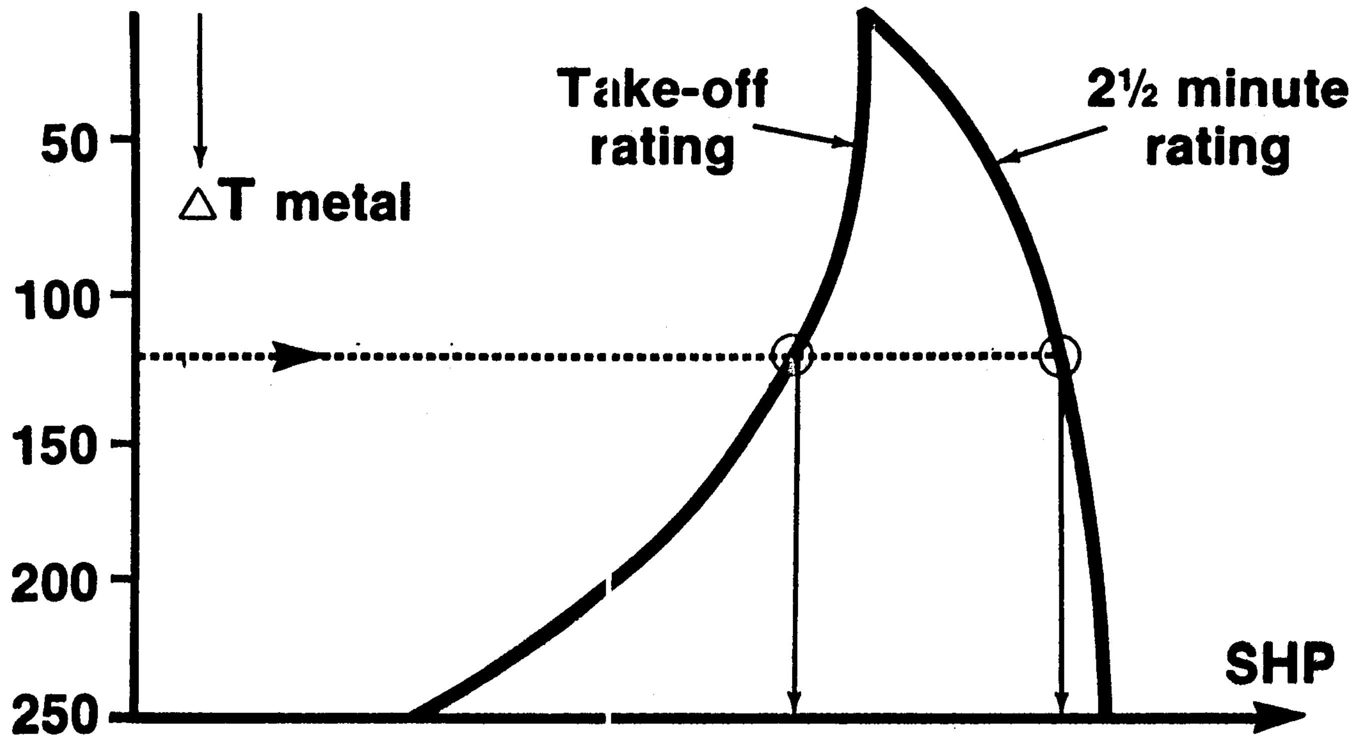
Maximum T metal
at emergency
rating



T metal ⟶ Rotor inlet temperature ⟶ SHP

C 1180 11190

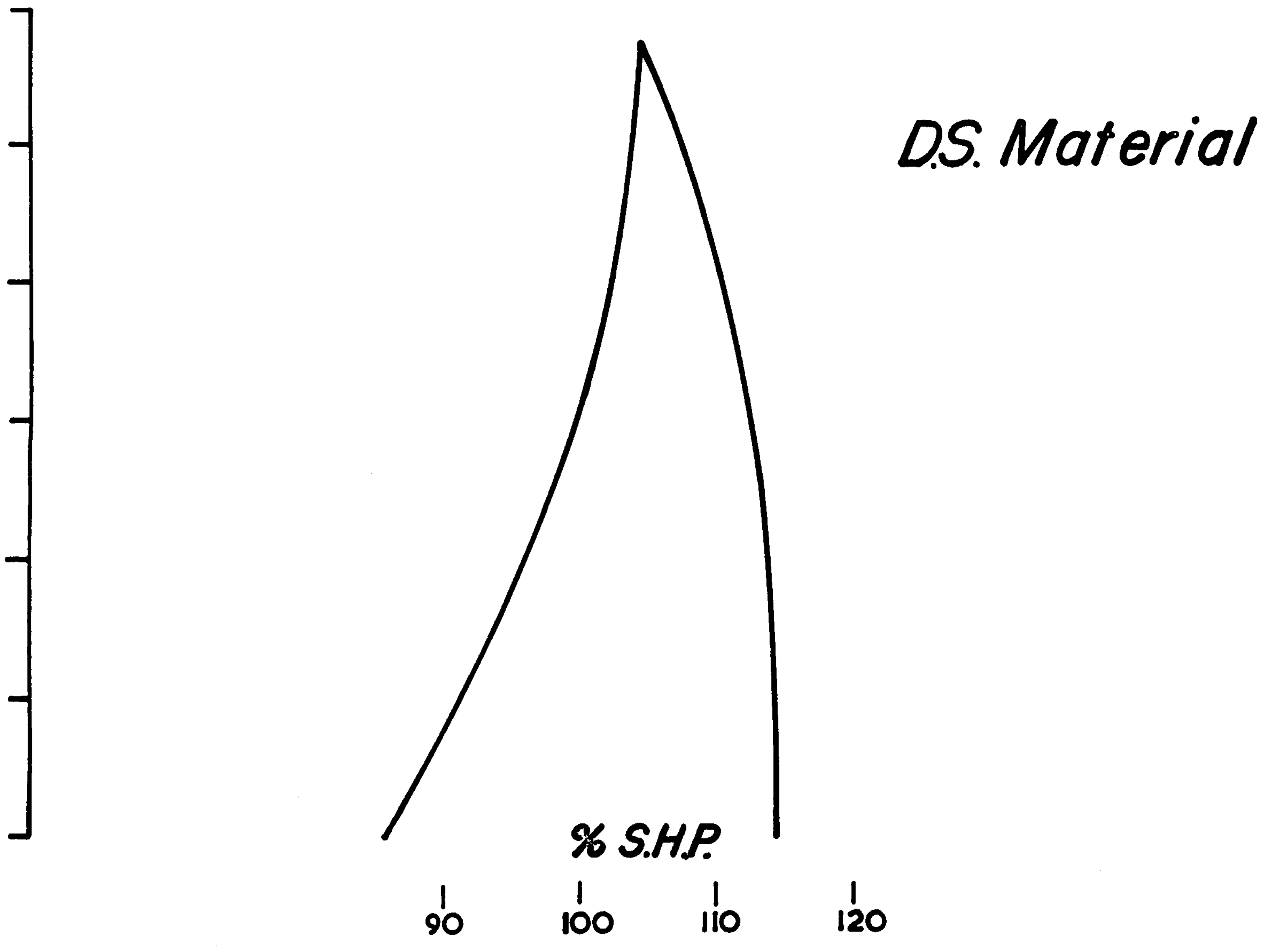
THE POWER PAIR LOCUS IS A PRELIMINARY DESIGN TOOL



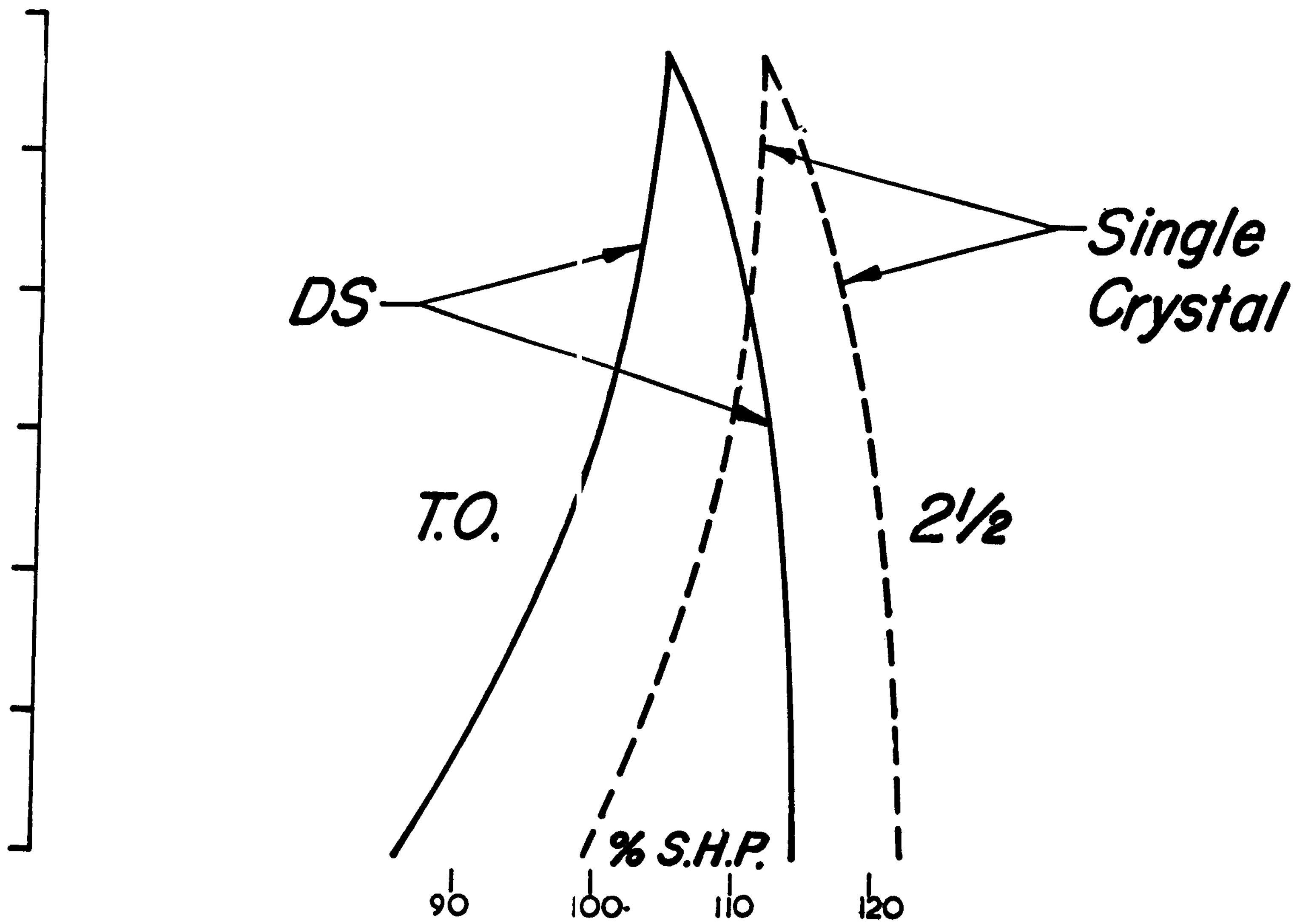
Δ T metal = T metal at 2½ minute power - T metal at take-off power

C1180 11189

TYPICAL POWER PAIR



POWER PAIRS
MATERIAL IMPROVEMENT



DESIGN TO JUST PASS TYPE TEST = GOOD SERVICE LIVES

TYPICAL TEST SCHEDULE (FAA & CAA)

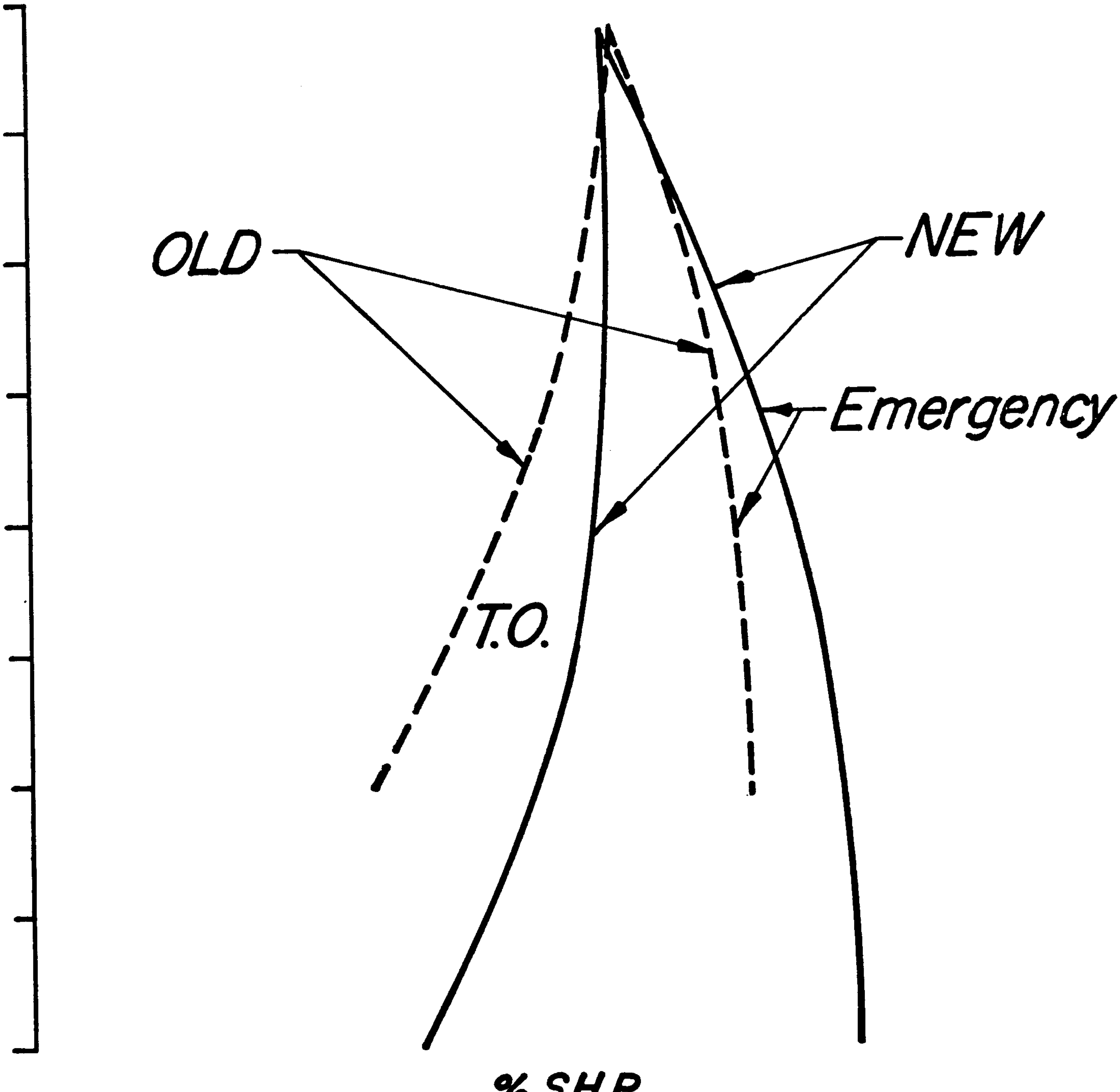
2½ min	2.08	hr
TAKE-OFF	46.25	hr
MAX. CONT.	40.8	hr
OTHERS	60.87	hr
	150.0	hr

IMPROVE TYPE TEST REALISM

REVISE SCHEDULE

EMERGENCY RATING	0.1	hr
TAKE-OFF	48.3	hr
MAX CONT	40.8	hr
OTHERS	60.9	hr
	150.1	hr

IMPROVEMENT FROM TYPE TEST REVISION



INCREASED EMERGENCY RATINGS

FOR THE PRESENT:

- INCREASE CAT 'A' PAYLOAD

FOR THE FUTURE:

- REDUCE ENGINE SIZE
- REDUCE POWERPLANT WEIGHT
- REDUCE FUEL BURN

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Dennis Lewis

Rolls Royce, Ltd.

Emergency power level

1. Defined as maximum power produced by engine and limited only by physical engine limit (e.g. fuel flow, temp. stop etc.)

2. Not a rating ?

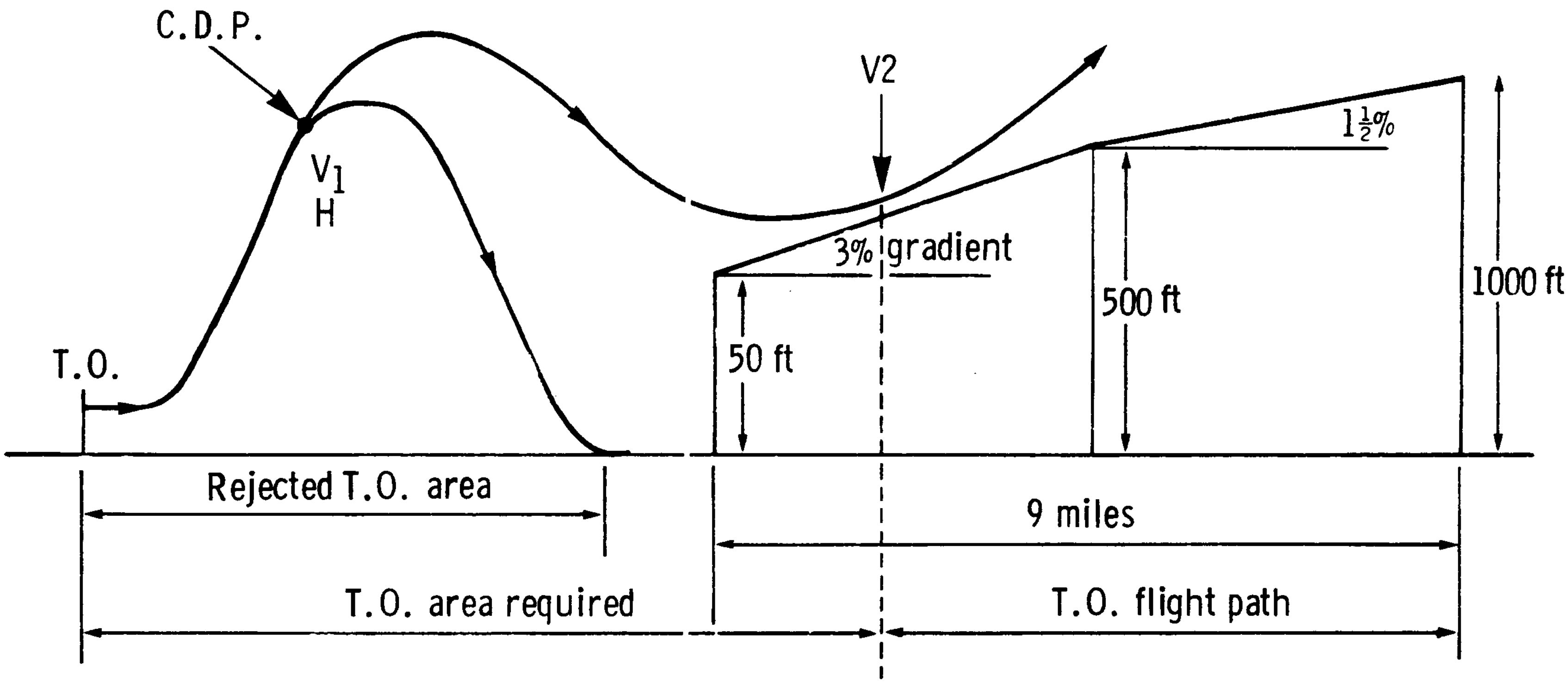
3. Supported by engine monitoring system

Why emergency power level

1) Category A. take-off.

2) Over water hover.

Category A take-off



Max power determines:-

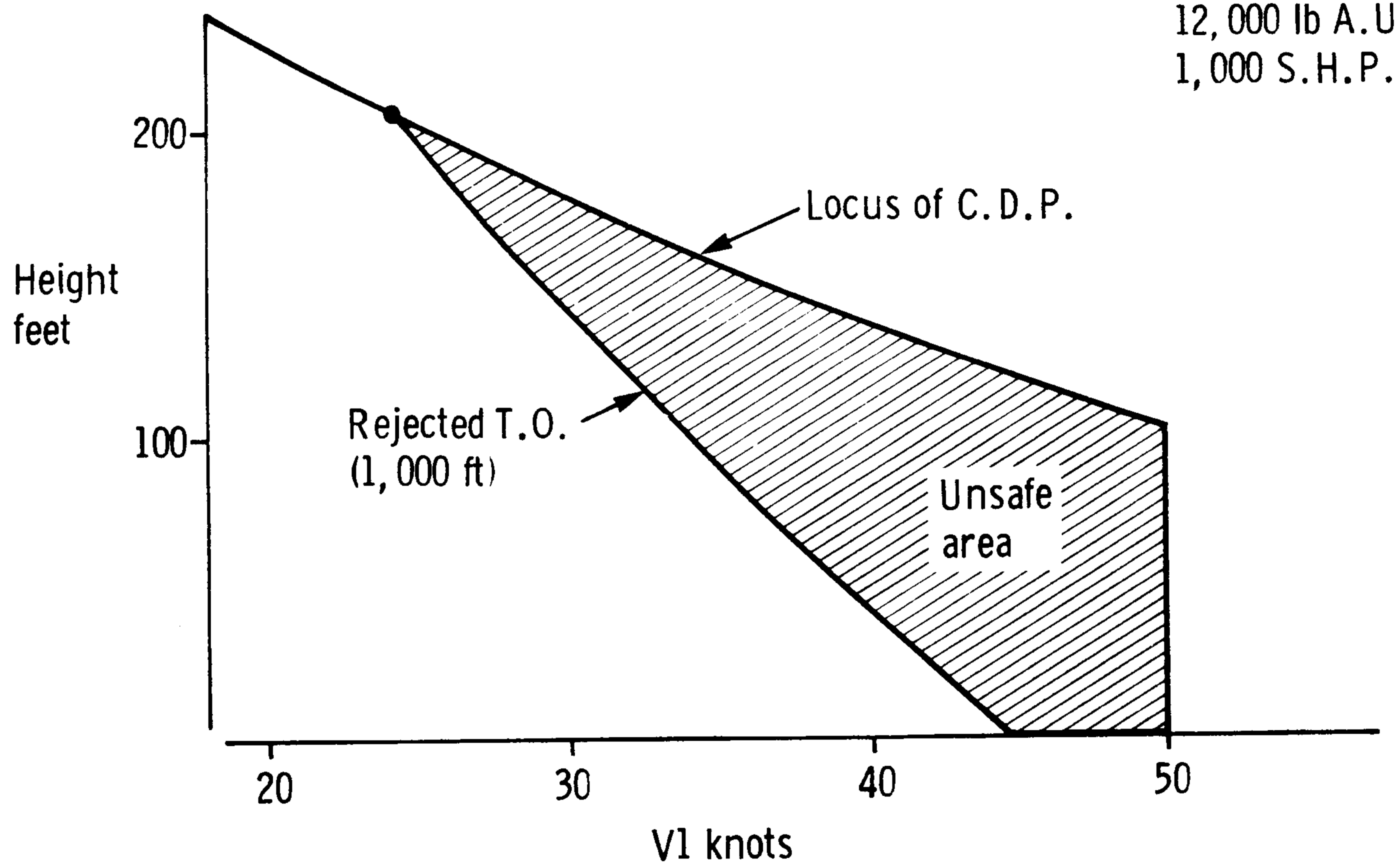
a) C.D.P. height & speed

b) Initial climb speed

L 1101

Approximate T.O. safety areas
(Max. contingency = +12 $\frac{1}{2}$% T.O.)

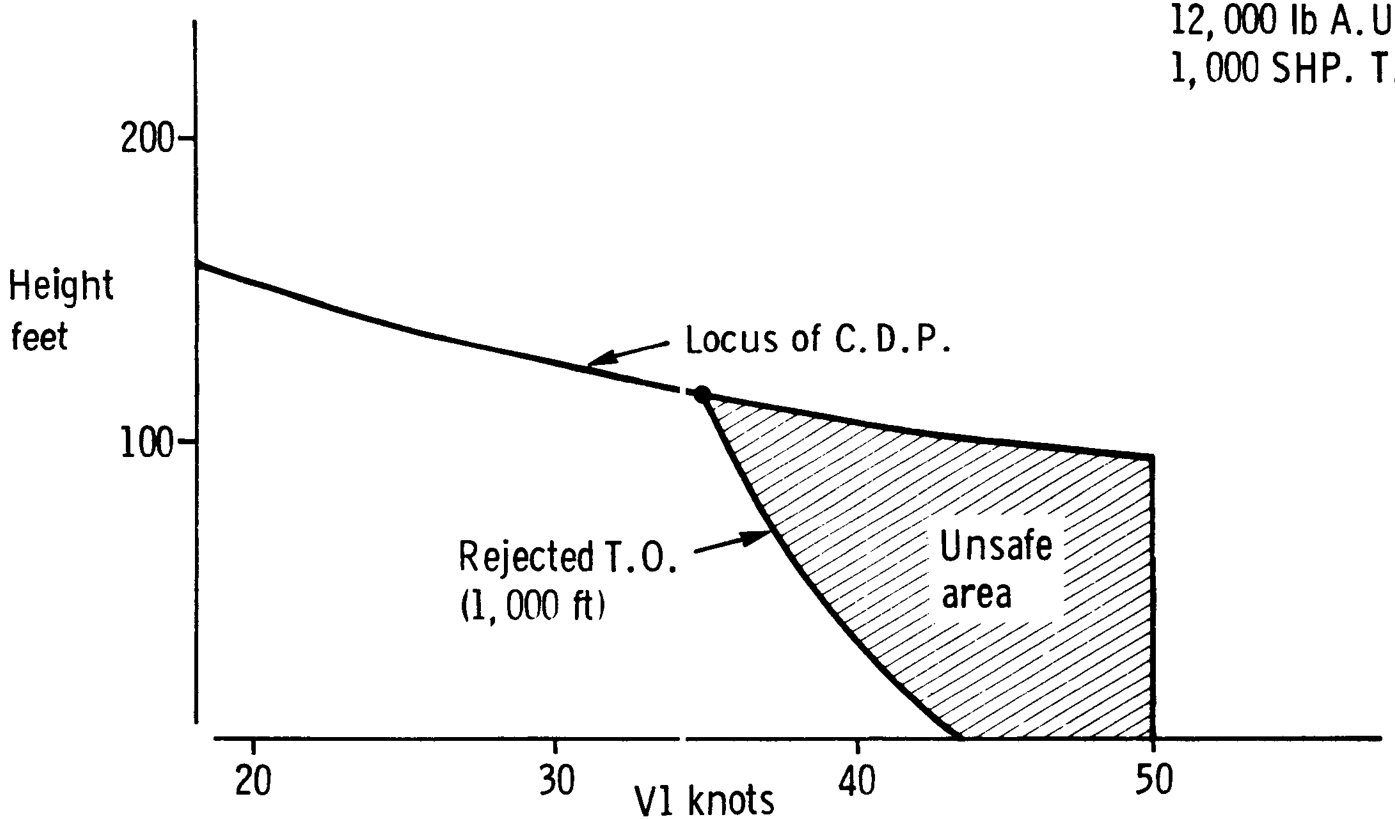
Typical for aircraft
12,000 lb A.U.W.
1,000 S.H.P. T.O.



L 1102

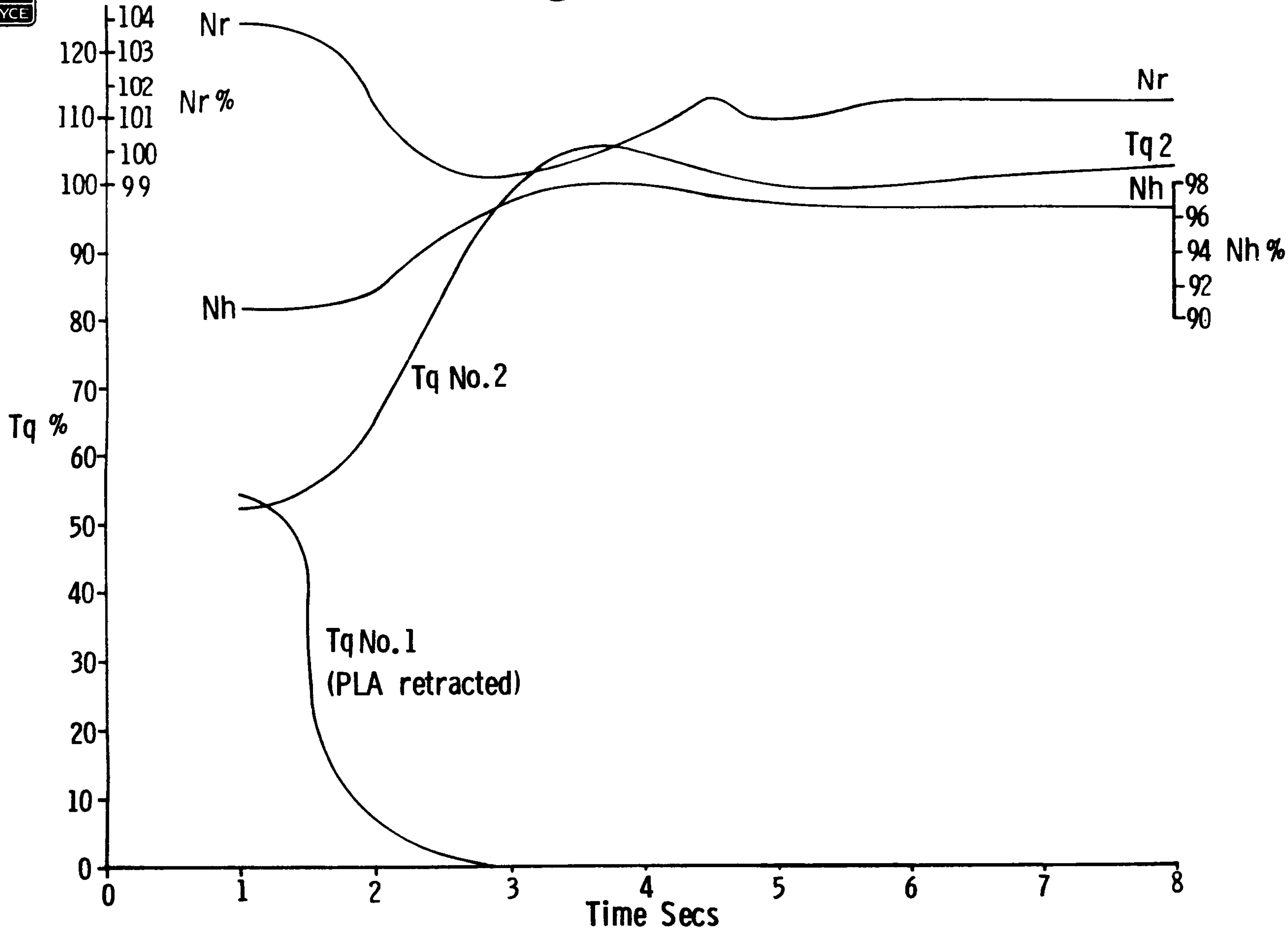
Approximate T.O. safety areas
(Max. contingency = + 24 %T.O.)

Typical for aircraft
12,000 lb A.U.W.
1,000 SHP. T.O.



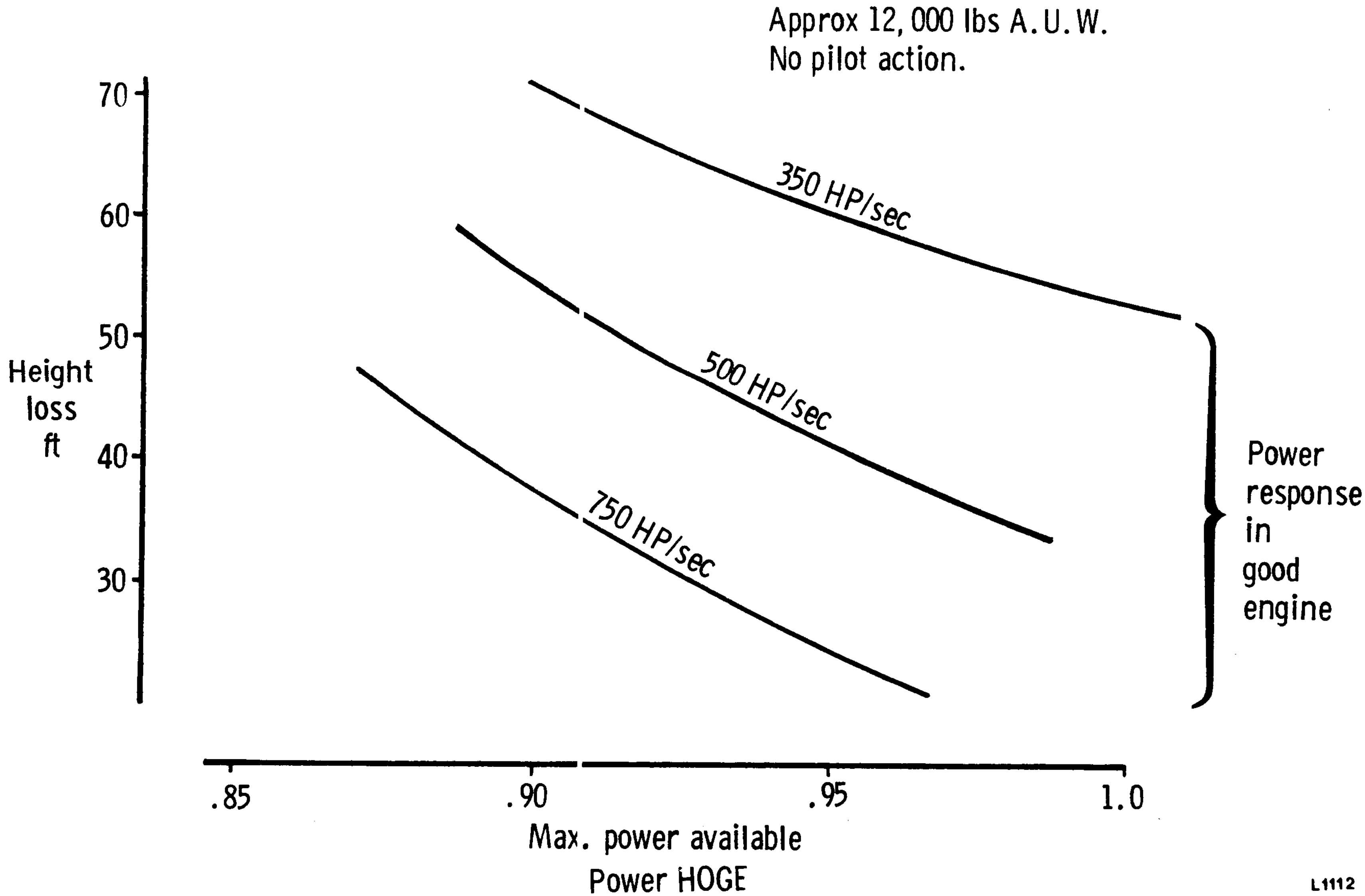
L1105

Simulated engine failure response



L948/1

Typical height loss vs power available



L1112

Clearance of emergency power level

1. Time per application.	60 secs	30 secs
2. Max no. of applications (between action being necessary).	3	3
3. Demonstration requirements within 150 hr type test run following additional test at end of stages 12, 24 & 25 (non external bleed stages).	a) Accel. from F.1. to E.P. b) $1\frac{1}{2}$ mins at E.P. c) Decel. to F.1. d) Repeat a, b & c (Total 9 mins extra).	b) 45 secs at E.P. (Total $4\frac{1}{2}$ mins extra).
4. Supplementary test consideration.	Blade containment - re-assess against increase in MAX. RPM (where appropriate).	

L1108

Integrated monitoring system

Typical maintenance display
port engine

Engine hours	1450	Starts 1505
L.C.F. Usage in cycles	L.P.C. 1050	L.P.T. 1105
	H.P.C. 1103	H.P.T. 1164
	P.T. 1514	
Creep usage	H.P. 15% units	
	L.P. 10%	
Power margin	plus 15% at I.S.A. Port	
	plus 10% at I.S.A. Starboard	

Exceedances

T_6 overtemp. by 30^{0} C for 20 sec.

Vibration over limit 2.5 in./sec at 95% N_H

Electronic control system

Failure Mode Philosophy
(Twin engine helicopters)

1)	Fail freeze	—	for aircraft with optimised power levels for high duty roles (ASW, oil rigs etc.)
2) OR	Fail down Fail to mid power.	—	for aircraft with excess of power in normal operation.

ROLLS-ROYCE LIMITED LEAVESDEN
WATFORD WD2 7BZ ENGLAND

Telegrams: Rollsed Watford Telephone: Garston (092-73) 74000 Telex: 23206

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Edward Peace

Avco Lycoming

PROBLEMS CONFRONTING HELICOPTER PROPULSION

- CONTROL SYSTEMS
  - OLD TECHNOLOGY
    - RELIABILITY
  - NEW TECHNOLOGY
    - INDEPENDENT ACTION BEING TAKEN
      - TOO SLOW
      - NOT STANDARDIZED
      - LOW FUNDING AS COMPARED TO 1960 - 1956 ERA

- OVERSPEED TRIP SYSTEMS
  - FAA INTENDS TO IMPOSE AN OVERSPEED TRIP SYSTEM OFF P. T. SHAFT OR 1ST POWER MESH
  - ELECTRONIC
    - RELIABILITY
    - TOO MANY APPROACHES
      - LACK OF STANDARDIZATION
      - LACK OF PILOT TRUST

AVCO LYCOMING DIVISION
STRATFORD, CONN.

PROBLEMS CONFRONTING HELICOPTER PROPULSION (CONTINUED

    - RADIO INTERFERENCE (INADVERTENT TRIPS)
    - WEIGHT
  - MECHANICAL
    - TOO LITTLE EFFORT EXPENDED

- ENGINE INDICATORS
  - POOR ACCURACY
  - UNRELIABLE
  - IMPACT ON ENGINE MAINTENANCE COST
  - ALLOWS ENGINE(S) TO EXCEED OPERATIONAL LIMITS (PARA. 27.1521 AND 29.1521)

CONTROLS

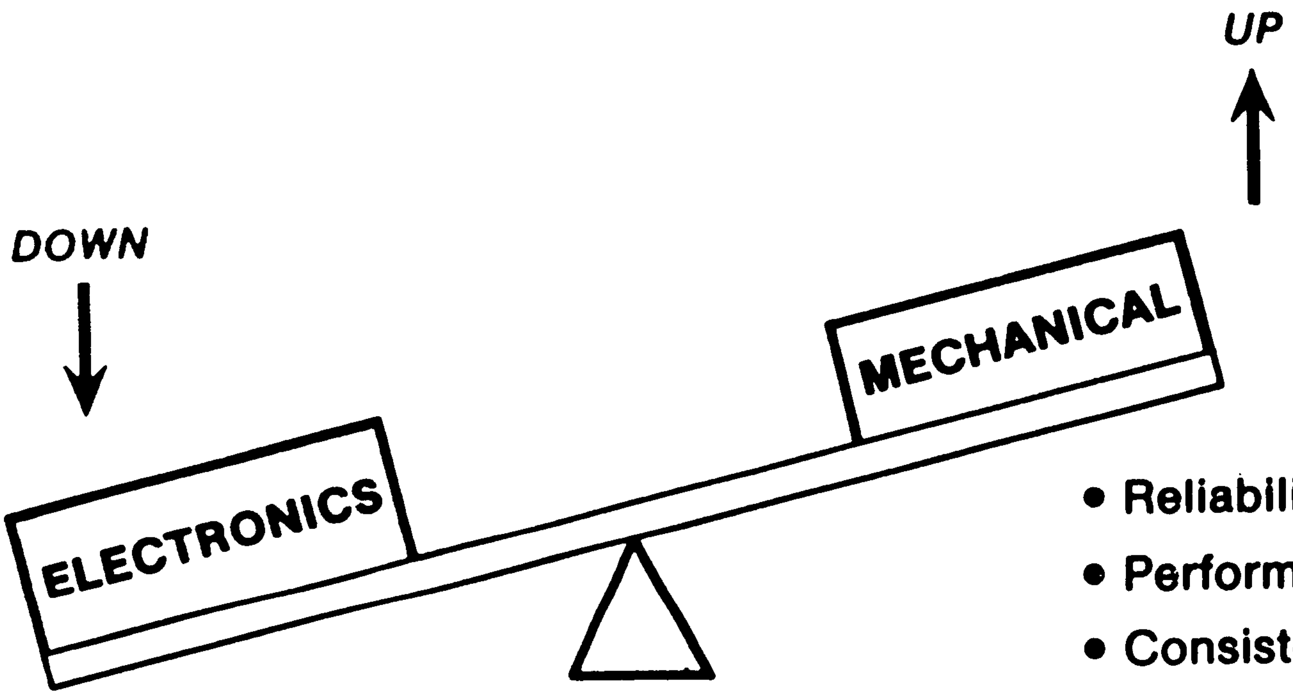
- o SMALL ENGINE CONTROLS (EXISTING)
  - o COST
    - o DRIVES SMALL ENGINES TO COMMON CONTROL
  - o TECHNOLOGY
    - o OLD (1960 - 1965 VINTAGE)
    - o FLOWING PNEUMATIC
      - o SENSITIVE
        - o CORROSION
        - o CONTAMINATION
        - o AIR LEAKS

C-3

AVCO LYCOMING DIVISION
STRATFORD, CONN.

CONTROLS (CONTINUED)

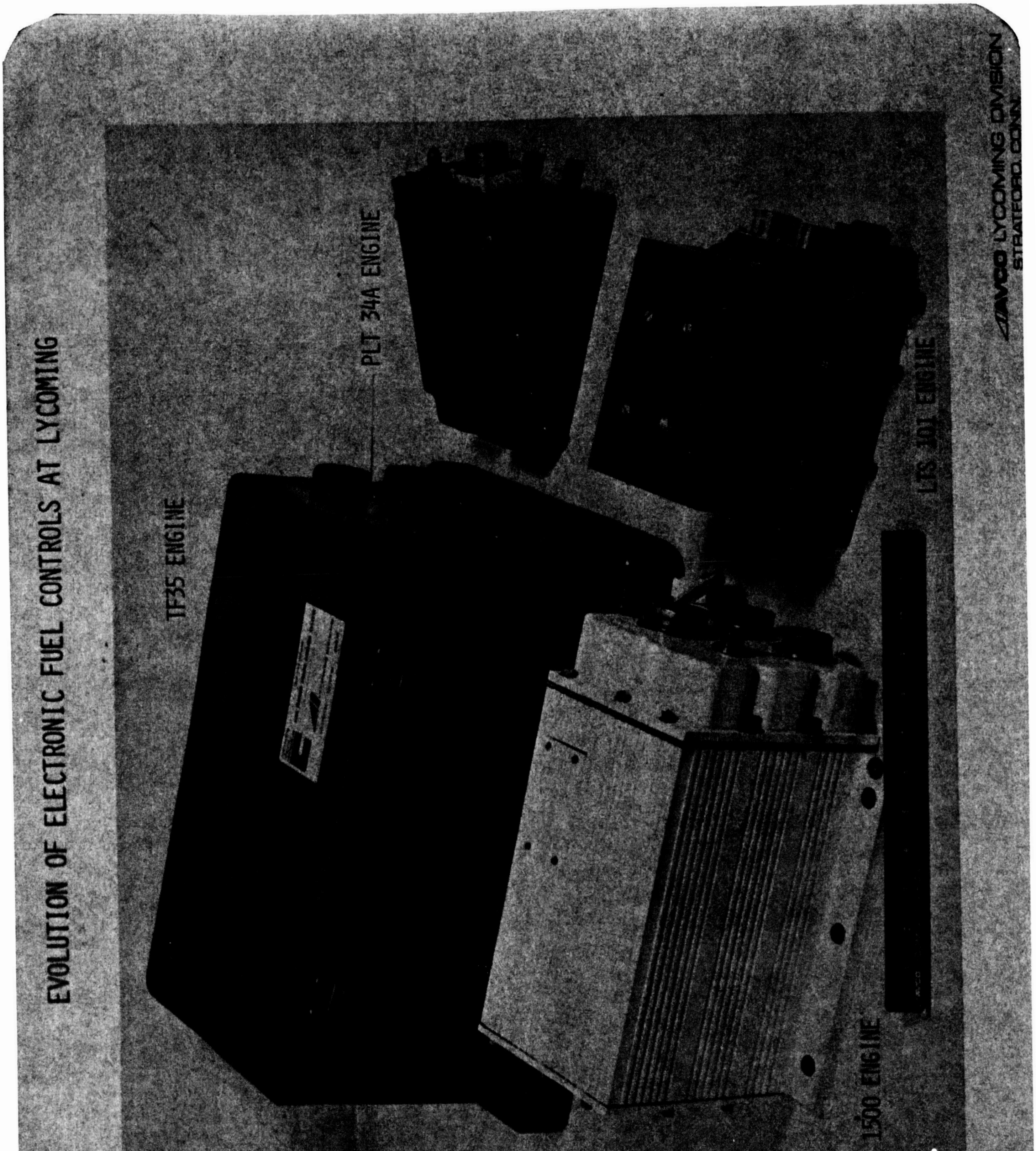
- SMALL ENGINE CONTROLS (NEW)
  - HYDRO MECHANICAL
    - COST
  - ELECTRONIC
    - NEW TECHNOLOGY
      - ISOCHRONOUS GOVERNING (NO BEEPER)
      - TORQUE MATCHING/LIMITING
      - LESS COMPLEXITY (EASIER INSTALLATION)
      - IMPROVED WAVEOFF SURGE MARGINE
  - BACKUP (REDUNDANCY)



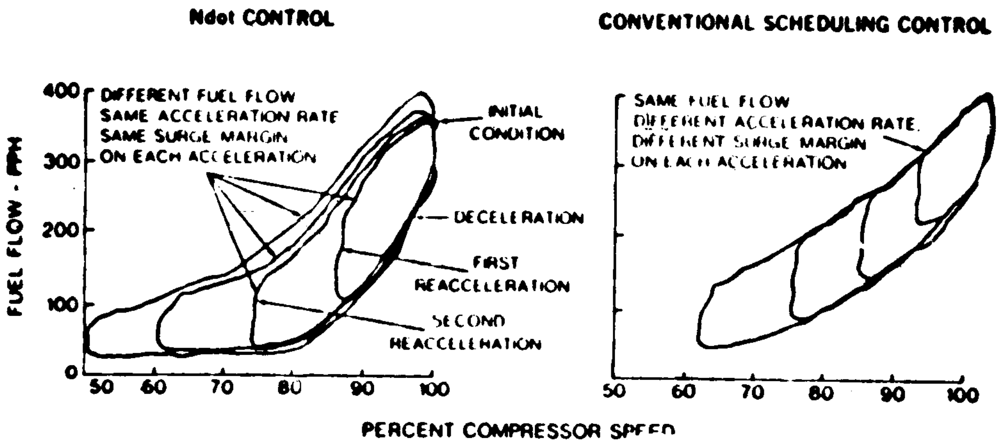
- Size and Weight
- Cost
- Adjustments
- Set-Up Time

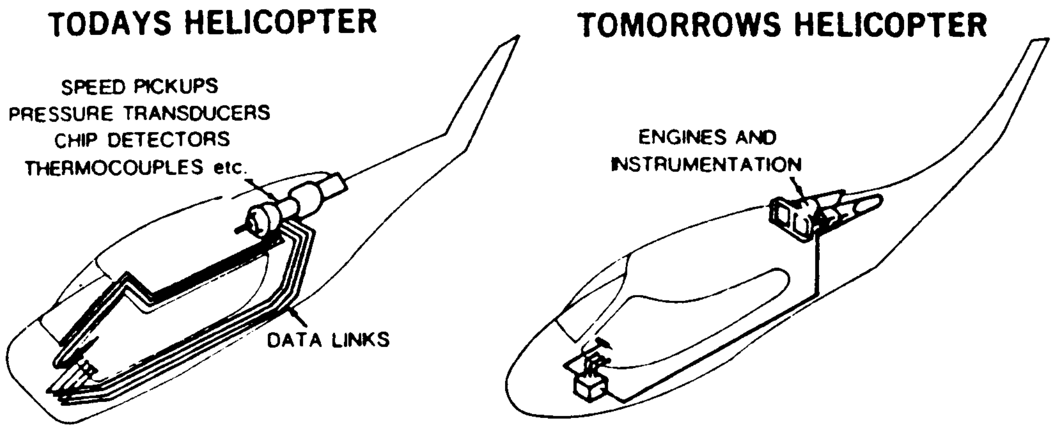
- Reliability
- Performance
- Consistency
- Accuracy
- Flexibility

AVCO LYCOMING DIVISION
STRATFORD, CONN.



ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH


Ndot CONTROL
CONVENTIONAL SCHEDULING CONTROL
DIFFERENT FUEL FLOW
SAME ACCELERATION RATE
SAME SURGE MARGIN
ON EACH ACCELERATION
INITIAL CONDITION
DECELERATION
FIRST REACCELERATION
SECOND REACCELERATION
SAME FUEL FLOW
DIFFERENT ACCELERATION RATE
DIFFERENT SURGE MARGIN
ON EACH ACCELERATION
FUEL FLOW - PPH
400
300
200
100
0
50
60
70
80
90
100
PERCENT COMPRESSOR SPEED


TODAYS HELICOPTER
SPEED PICKUPS
PRESSURE TRANSDUCERS
CHIP DETECTORS
THERMOCOUPLES etc.
DATA LINKS
TOMORROWS HELICOPTER
ENGINES AND
INSTRUMENTATION

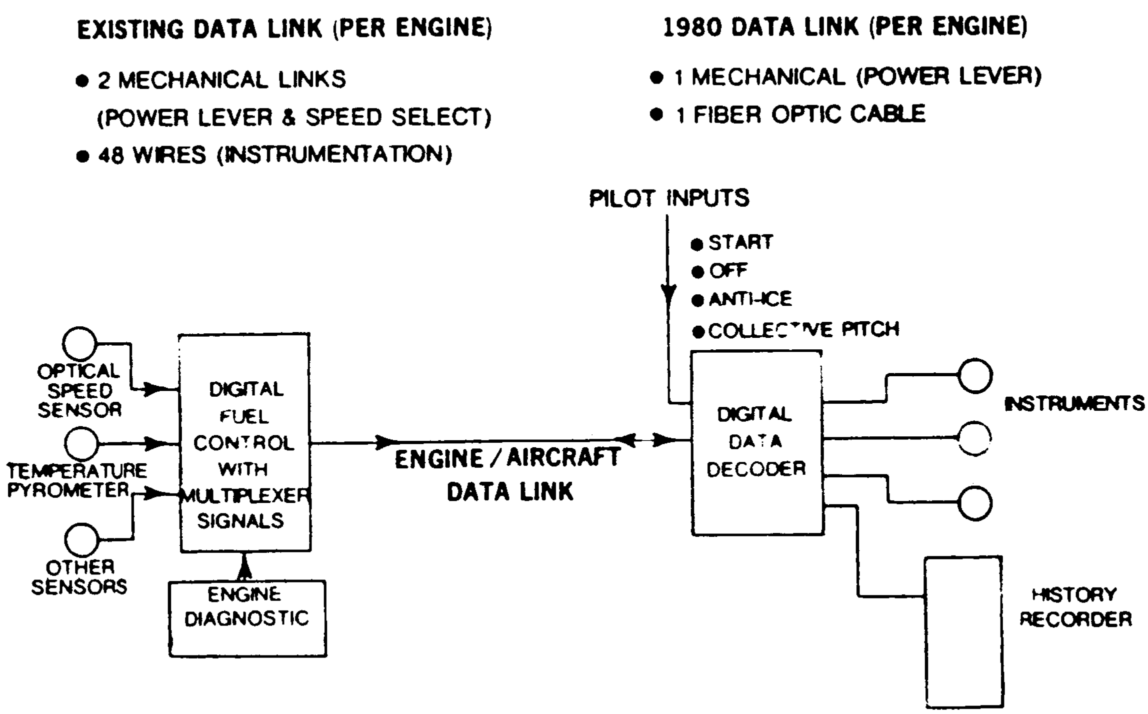
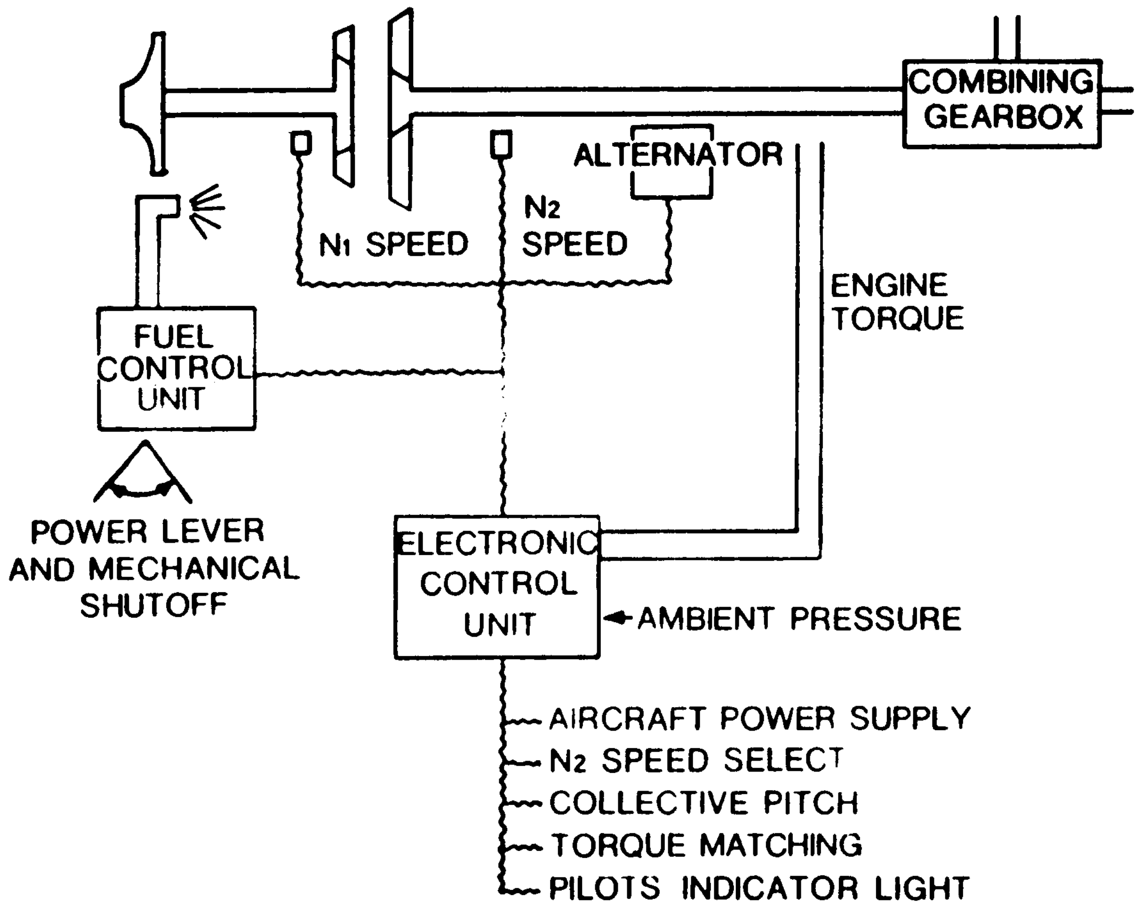
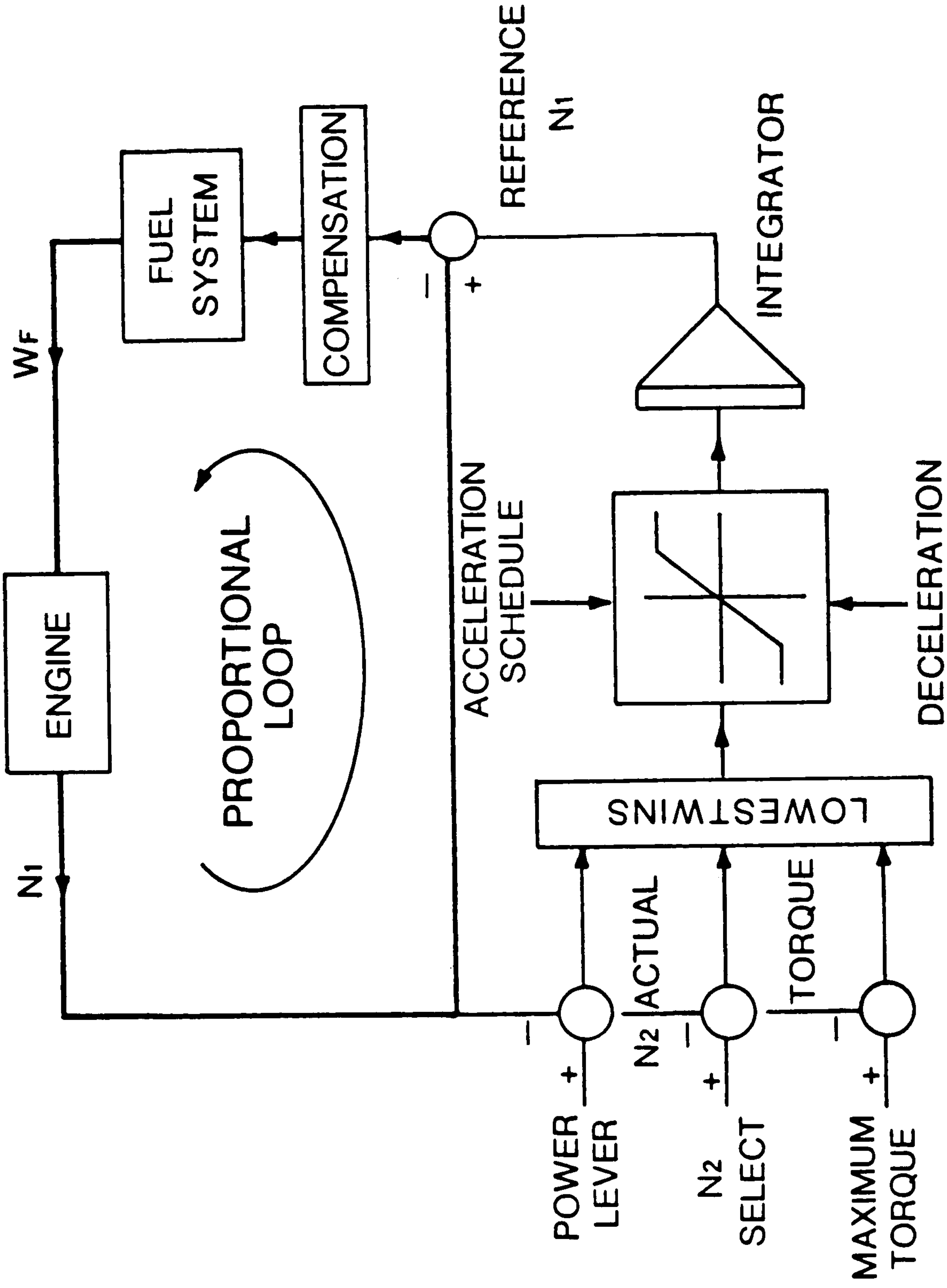

EXISTING DATA LINK (PER ENGINE)
• 2 MECHANICAL LINKS
(POWER LEVER & SPEED SELECT)
• 48 WIRES (INSTRUMENTATION)
1980 DATA LINK (PER ENGINE)
• 1 MECHANICAL (POWER LEVER)
• 1 FIBER OPTIC CABLE
PILOT INPUTS
• START
• OFF
• ANTI-ICE
• COLLECTIVE PITCH
OPTICAL SPEED SENSOR
TEMPERATURE PYROMETER
OTHER SENSORS
DIGITAL FUEL CONTROL WITH MULTIPLEXER SIGNALS
ENGINE DIAGNOSTIC
ENGINE / AIRCRAFT DATA LINK
DIGITAL DATA DECODER
INSTRUMENTS
HISTORY RECORDER

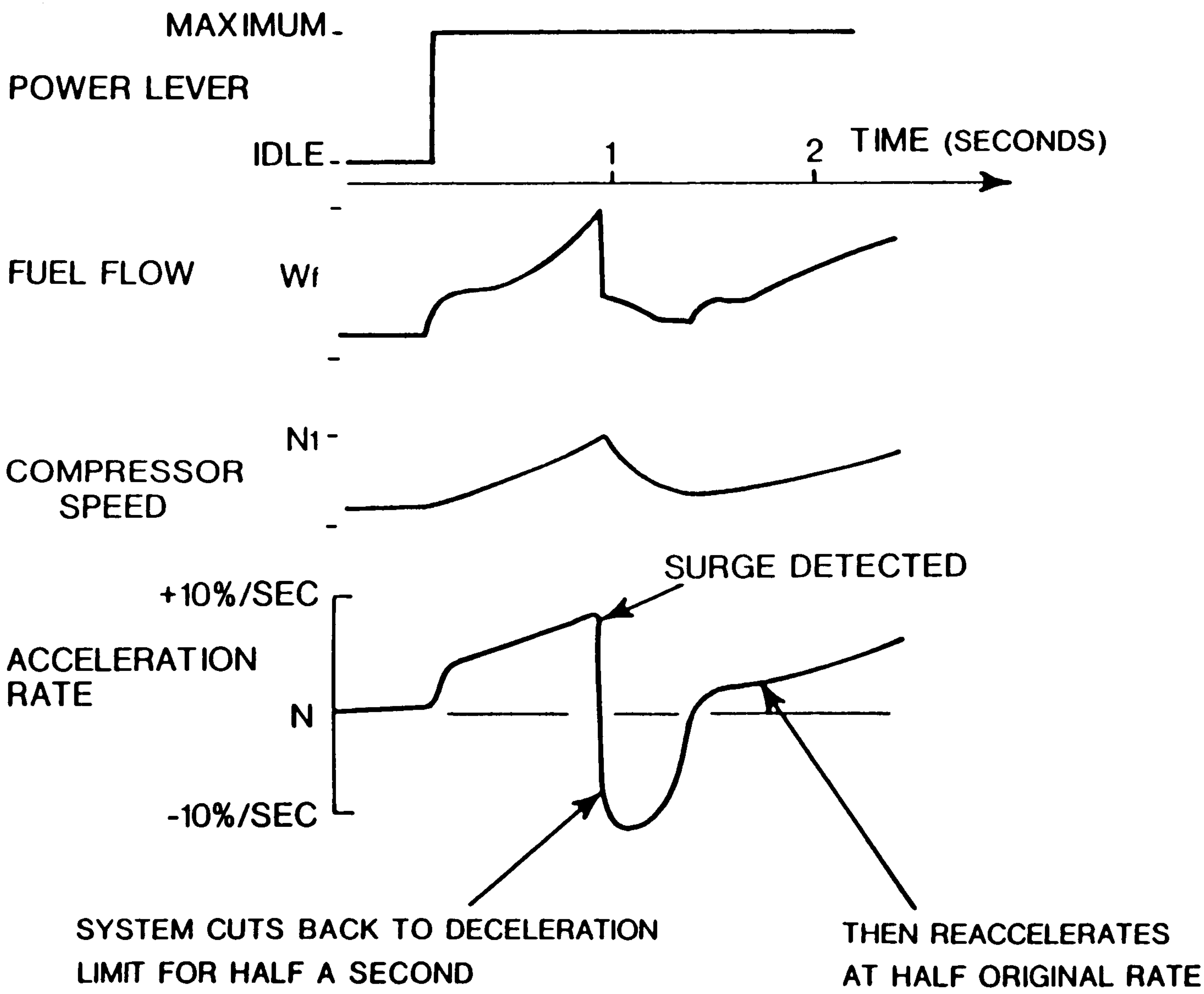
Figure 12.

FIGURE 5



COMBINING GEARBOX
ALTERNATOR
N_1 SPEED
N_2 SPEED
ENGINE TORQUE
FUEL CONTROL UNIT
POWER LEVER AND MECHANICAL SHUTOFF
ELECTRONIC CONTROL UNIT
AMBIENT PRESSURE
AIRCRAFT POWER SUPPLY
N_2 SPEED SELECT
COLLECTIVE PITCH
TORQUE MATCHING
PILOTS INDICATOR LIGHT


ENGINE
FUEL SYSTEM
COMPENSATION
REFERENCE N_1
INTEGRATOR
PROPORTIONAL LOOP
W_F
N_1
ACCELERATION SCHEDULE
DECELERATION SCHEDULE
LOWESTWINS
N_2 ACTUAL
TORQUE
POWER LEVER
N_2 SELECT
MAXIMUM TORQUE


MAXIMUM
POWER LEVER
IDLE
1
2
TIME (SECONDS)
FUEL FLOW
Wf
COMPRESSOR SPEED
N1
+10%/SEC
ACCELERATION RATE
N
-10%/SEC
SURGE DETECTED
SYSTEM CUTS BACK TO DECELERATION LIMIT FOR HALF A SECOND
THEN REACCELERATES AT HALF ORIGINAL RATE

OVERSPEED TRIP SYSTEMS

- TYPICAL SYSTEMS (ACCEPTABLE)
  - OFF POWER TURBINE (LARGE ENGINES)
  - OFF POWER SHAFT
  - DEDICATED GEAR TRAIN OFF POWER SHAFT
  - DEDICATED GEAR TRAIN OFF 1ST POWER MESH
  - OFF 1ST POWER MESH
- ELECTRONIC SYSTEM
  - WEIGHT
  - RELIABILITY
    - PROBLEMS WHEN ENGINE MOUNTED
  - RFI SUSCEPTIBILITY
    - USUALLY DUE TO TEST SWITCH LOOP
  - ANALOG
  - DIGITAL
  - DUAL TRIP (ANALOG/DIGITAL)
  - NEED FOR STANDARDIZATION

AVCO LYCOMING DIVISION
STRATFORD, CONN.

OVERSPEED TRIP SYSTEMS (CONTINUED)

- MECHANICAL
  - PRESENT SYSTEM LIMITED TO 6300 RPM
    - VERY RELIABLE
  - DIFFICULT TO TAKE OFF 1ST MESH
    - NEED FOR HIGHER SPEED (12000 + RPM) WITH SAME RELIABILITY

ENGINE INDICATORS

- MEASURED GAS TEMPERATURE INDICATORS
  - RANGE FROM $\pm 3^{\circ}C$ TO $\pm 30^{\circ}C$
  - IMPACT POWER ASSURANCE
  - IMPACT DIRECT OPERATING COST
  - LACK OF STANDARDIZATION
- N_P/N_R SPEED INDICATOR
  - DUAL TACH NOT REQUIRED BY FAR 27
  - N_R SPEED INDICATOR ACCURACY
    - INDICATE AS MUCH AS 7% LOW
      - AFFECTS POWER ASSURANCE
      - AFFECTS OVERSPEED TRIP
      - AFFECTS D. O. C.
- TORQUEMETER
  - ENGINE MOUNTED TRANSDUCER RELIABILITY
  - TEMPERATURE EFFECT ON TRANSDUCER ACCURACY USUALLY IGNORED
    - AFFECTS POWER ASSURANCE
    - AFFECTS D. O. C.